# Operating and Maintenance Handbook

MARCONI INSTRUMENTS LIMITED, ENGLAND

F.M. SIGNAL GENERATOR

TYPE TF 1066B

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# OPERATING AND MAINTENANCE

# HANDBOOK

for

# F.M. SIGNAL GENERATOR

# TYPE TF 1066B

AMENDMENTS, where applicable, are included at the end of the handbook.

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(Follows Page 29)

## SCHEDULE OF PARTS SUPPLIED

The complete equipment comprises the following items:-

1. One F.M. Signal Generator Type TF 1066B complete with attached mains lead and valves etc. as under:-

| | | |
|---|---|---|
| Valves: | One: | Type 5Z4G, Full-Wave Rectifier. |
| | One: | Type 6AK6, Pentode. |
| | One: | Type TDO3-10E (CV5458), Disk-Seal Triode. |
| | One: | Type 6AK5 (EF95), Pentode. |
| | One: | Type 6C4 (L77), Triode. |
| | One: | Type 12AX7, Double Triode. |
| | One: | Type 6L6G (KT66), Tetrode. |
| | One: | Type 6CD6G, Tetrode. |
| | One: | Type OB2 (QS1208), Voltage Stabilizer. |
| | One: | Type 5651(QS1209), Voltage Stabilizer |
| Transistors: | Two: | Type GET 114. |
| | One: | Type CTP 1109. |
| Semiconductors: | Two: | Type CG1E, Germanium Diodes. |
| | One: | Type CS2A, Silicon Diode. |
| Fuses: | Two: | 2-amp, Cartridge. |
| | One: | 0.25-amp, Cartridge. |
| | Two: | 1-amp, Cartridge. |
| Lamp: | One: | 6.3-volt, 0.15-amp, M.B.C. Pilot Lamp. |

2. One Coaxial Free Plug, Type N, 50 Ω, for R.F. Output socket.

3. One CORRECTION CHART FOR DEVIATION AND INCREMENTAL FREQUENCY MONITOR (card to TC 25688), normally stowed in left-hand case-handle recess.

4. One Operation and Maintenance Handbook No. OM 1066B.

The following output accessories are optional items supplied only if specially ordered.

5. Output Lead, 50-ohm, Type TM 4824.

Schedule of Parts Supplied (continued)

6. 20-dB Pad, 50-ohm, Type TM 4919.

7. 6-dB Pad, 50-ohm, Type TM 4919/1.

8. Matching Unit, 50 ohm to 75 ohm, Type TM 4918.

9. Matching Unit, 50 ohm Unbalanced to 300 ohm Balanced, Type TM 4916.

10. D.C. Isolating Unit Type TM 4917.

11. Coaxial Fuse Type TM 5753; prevents damage to the Signal Generator attenuator through accidental application of r.f. or h.t. power to the circuit under test.

| | |
|---|---|
| Overload Protection: | Burns out at 0.4 watt. |
| Insertion Loss: | Nominally 0.5 dB. |
| V.S.W.R.: | 1.35 or less when terminated with a matched 50-ohm load. 1.6 or less when terminated with TF 1066B attenuator via 20-dB Pad TM 4919. |
| Connectors: | Type N. |
| Fuse: | 1/16 amp 'Littelfuse' Cat. No. 361.062. 10 spares are supplied. |

# DATA SUMMARY

for

# F.M. SIGNAL GENERATOR

# TYPE TF 1066B

## FREQUENCY

| | |
|---|---|
| Ranges: | Band A: 10 to 22 Mc/s.<br>Band B: 22 to 48 Mc/s.<br>Band C: 48 to 110 Mc/s.<br>Band D: 110 to 240 Mc/s.<br>Band E: 240 to 470 Mc/s. |
| Main Tuning Control: | Operates via precision slow-motion drive; frequency dial has a total scale length of approximately 60 inches. |
| Calibration Accuracy: | 1.0%. |
| Frequency Stability: | After warm-up, the drift is not greater than 0.0025% in a 10-minute period. |
| Fine Tuning Control: | A total cover of the order of 25 kc/s is provided by means of an uncalibrated control. |
| Incremental Frequency-Control: | Carrier shift is variable from -100 to +100 kc/s by continuous and stepped control. The stepped control has three negative and three positive shift positions, each with independent preset adjustment, and one zero shift position. Shift is monitored by meter with two ranges, -20 to +20 kc/s and -100 to +100 kc/s. |

| | |
|---|---|
| Incremental Accuracy: | Accuracy varies inversely with carrier frequency from within 10% to within 20% of f.s.d. Using correction chart supplied, accuracy at all carrier frequencies is within 10% of f.s.d. |
| Spurious Signals: | Total harmonic content is less than 10%. There are no sub-harmonics. |

R.F. OUTPUT

| | |
|---|---|
| Level: | The source e.m.f. is continuously variable from 0.2 μV to 200 mV. The attenuator dial shows the source e.m.f. both directly and in decibels relative to 1 μV. The dial cursor can be positioned to indicate voltage across a 50-ohm load instead of source e.m.f. |
| Output Accuracy: | Incremental, 0.2 dB; overall,2 dB. |
| Source Impedance: | 50 ohms; v.s.w.r. not greater than 1.25:1 using the 20-dB pad TM 4919, or 1.6 using the 6-dB pad TM 4919/1. |
| Attenuator Reaction: | Negligible below 50 mV; not greater than 0.1% above. |
| Stray Radiation: | Negligible; permits full use of lowest output. |

FREQUENCY MODULATION

| | |
|---|---|
| Internal: | Modulation frequencies: 1 and 5 kc/s. Deviation variable to 100 kc/s maximum and indicated on two meter ranges, 0 to 20 kc/s and 0 to 100 kc/s. |
| External: | Modulation frequency range: 30 c/s to 15 kc/s. Deviation as for INTERNAL. Input requirements: 25 volts across 5 kΩ for 100 kc/s deviation. |

| | |
|---|---|
| Deviation Accuracy: | Internal Modulation; Accuracy varies inversely with carrier frequency from within 7% of f. s. d. to within 20% of f. s. d.; using correction chart supplied, accuracy at all carrier frequencies is within 7% of f. s. d. |
| | External Modulation: Accuracy over the modulation frequency range is within 5% of accuracy at 1 kc/s. |
| A. M. on F. M.: | Typically, less than 5% modulation depth at maximum deviation. |
| Residual F. M.: | The f. m. due to hum and noise is less than 100 c/s deviation. |

AMPLITUDE MODULATION

| | |
|---|---|
| Internal: | Modulation frequencies; 1 and 5 kc/s. Modulation depth variable up to at least 40% and indicated on two meter ranges, 0 to 20% and 0 to 100%. |
| External: | Modulation frequency range: 30 c/s to 15 kc/ s. Modulation depth as for INTERNAL. Input requirements: 10 volts across 1 MΩ for 40%. |
| Modulation Depth Accuracy: | ±2% modulation on 0 to 20% range. ±5% modulation on 0 to 100% range. |
| F. M. on A. M.: | For 30% a. m., varies typically from 4 kc/s at 10 Mc/s to 60 kc/s at 100 Mc/s. |
| Residual A. M.: | The a. m. due to hum and noise is better than 50 dB below 30% modulation. |
| POWER SUPPLY: | 200 to 250 volts and 100 to 130 volts, 40 to 60 c/s; 90 watts. Fuses in mains, d. c. l. t., and h. t. circuits. |

| DIMENSIONS AND WEIGHT: | Height | Width | Depth | Weight |
|---|---|---|---|---|
| | 14½ in (37 cm) | 23½ in (60 cm) | 10½ in (27 cm) | 54 lb (24.5 kg) |

# 1 DESCRIPTION

## 1.1 GENERAL

The Marconi TF 1066B Signal Generator covers the carrier-frequency range 10 to 470 Mc/s. The primary purpose of the instrument is to provide c.w. or frequency-modulated outputs, but amplitude-modulated outputs can also be obtained. The open-circuit voltage is continuously variable from 0.2 μV to 200 mV, and the output impedance is 50 ohms.

Tuning and Incremental Frequency Controls. The frequency range is covered in five bands; each band has its own directly calibrated scale on the main tuning dial.

For general tuning there are two controls. One is the normal or COARSE TUNING control linked to the main tuning dial, and the other is an uncalibrated FINE TUNING control, which has a total cover of the order of 25 kc/s.

Small precise changes up to ± 100 kc/s can be made in carrier frequency by continuously variable and stepped controls. The stepped control has three negative and three positive shift positions, each with independent pre-set adjustment, and one zero shift position. Both the continuously variable and stepped shifts are indicated directly on the appropriate scales of the MODULATION & INCREMENTAL FREQUENCY meter. This meter has two incremental scales selected by means of a switch. One scale is calibrated at 10-kc/s intervals from -100 kc/s to +100 kc/s, and the other is calibrated at 2-kc/s intervals from -20 kc/s to +20 kc/s.

Modulation. Frequency modulation can be applied at any deviation up to 100 kc/s. A built-in a.f. oscillator provides the internal modulating signal. The frequency of this oscillator is 1 kc/s or 5 kc/s depending upon the setting of a selector switch. External f.m. can be applied at any frequency between 30 c/s and 15 kc/s. For both internal and external modulation, the deviation is indicated directly in kc/s on the modulation scales of the MODULATION AND INCREMENTAL FREQUENCY meter.

Amplitude modulation can be applied at any depth up to at least 40% from the same sources - both internal and external - as for f.m. The modulation depth is indicated on the MODULATION AND INCREMENTAL FREQUENCY meter; the same scales are used for a.m. depth as for f.m. deviation. These scales are calibrated 0-20 and 0-100 respectively, the sensitivity being selected by means of a switch.

1.1 (continued)

R.F. Output Level. The r.f. output level of the Signal Generator is adjusted by means of a 50-ohm piston attenuator. The setting of the attenuator is indicated on a $4\frac{1}{2}$-inch dial having two scales - one calibrated directly in units of voltage and the other in decibels relative to 1 μV.

The cursor fitted to the attenuator dial is reversible. With one face of the cursor exposed, the hairlines indicate the source e.m.f. When the cursor is turned over, the indication is in terms of p.d. developed across a 50-ohm load.

1.2 DESIGN DETAILS

The general arrangement of the electrical circuits is shown on the Functional Diagram, Drawing No. XD 35453; the complete Circuit Diagram is given on Drawing No. XD 32922. These diagrams are included at the end of this manual.

Reference to these diagrams should assist the reader in fully-understanding the principles described in this section.

1.2.1 The R.F. Unit

Generating at the output frequency without the use of multipliers, the r.f. oscillator employs a disk-seal triode (V9) in a form of shunt-fed Colpitts circuit. The split-stator tuning capacitor is specially designed to have a low residual inductance. The stator plates are triangular and the two stator sections are arranged to mesh with a single set of rotor plates. There is a two-section set of stator plates for each of the five frequency bands, and the two sections of each set are linked by the appropriate tuning inductor, which is permanently attached to them.

The five stator-plate/tuning-inductor assemblies are mounted in a turret which is rotated by operation of the band-selector (RANGE) control. This turret is mounted coaxially with the capacitor-rotor spindle so that the rotor plates mesh with each set of stator plates in turn. The active stator assembly for the selected band is connected to the oscillator valve by a pair of coupling capacitors. These capacitors are formed by extensions of the stator plates meshing with fixed plates rigidly secured to the frame of the r.f. unit.

1.2.1 (continued)

The tuning-capacitor rotor is coupled mechanically to the main tuning dial by means of a one-to-one gear train and to the tuning control on the front panel by means of a 55:1 reduction gear. The gear system is spring-loaded throughout to reduce backlash to a minimum.

The level of output from the r.f. oscillator is monitored by a silicon-diode voltmeter (MR6 and M2) inductively coupled to the oscillatory circuit. When the Signal Generator is in use, the output of the oscillator is set up to a reference level - as indicated by a calibration mark on the meter scale - by means of the SET CARRIER control (RV2) which varies the oscillator h.t. voltage.

The piston attenuator is of the mutual-inductance type, and its pick-up element is fitted with a resistance-capacitance network which keeps the output impedance sensibly constant at 50 ohms despite change in frequency. A 50-ohm Type N plug is normally supplied with the instrument, and there are also several optional output-accessories available; these are listed in the Schedule of Parts Supplied.

The piston attenuator is coupled to its indicator dial by a rack-and-pinion drive mechanism. Like the main tuning drive, the attenuator-drive mechanism is spring loaded to reduce backlash. The panel control operates through a friction-type slow-motion drive.

1.2.2 Modulation.

The internal modulating signal is derived from a conventional Hartley oscillator utilizing a single triode valve (V1) and a tuned transformer (T1). The modulation-frequency selector (SB) brings into circuit the appropriate tuning capacitor to give either 1 kc/s or 5kc/s as required. The output level of this oscillator is varied by means of the SET MOD control. This control takes the form of a potentiometer (RV1) connected across the output of the modulation-oscillator circuit.

External modulation is introduced via a pair of terminals on the front panel. The modulating signal - either internal or external - is selected by means of switch SD. The setting of this selector switch also determines whether the signal is applied to the amplitude- or frequency-modulating circuit. The switch disconnects the h.t. of the modulating oscillator when set for c.w. or external modulation.

1.2.2 (continued)

Frequency modulation is effected by the use of a ferrite reactor (T3). In this type of modulator the inductance of a small r.f. coil is varied by permeability changes in its ferrite core. This core completes the magnetic circuit of an l.f. inductor whose winding carries the a.f. modulating current. The ferrite core is magnetically biased to a non-linear part of its B/H characteristic. Therefore, variations in the magnetic field strength, due to the a.f. modulating current, cause corresponding changes in the permeability of the ferrite core.

The a.f. modulating current is fed to the l.f. winding of the modulator via a pentode driver valve (V8).

For a constant f.m. deviation, the necessary magnitude of the modulator's reactance swing varies inversely with the carrier frequency. Or, in other words, the required level of a.f. drive to the modulator is not constant but decreases when the Signal Generator's output frequency is increased. It is desirable, however, that the level of a.f. input to the overall modulating system should remain constant. The modulating signal, therefore, is fed to the grid of the driver valve (V8) via a correcting network which is varied by both the main tuning control and the frequency-band selector switch.

The carrier is amplitude-modulated by direct anode modulation of the r.f. oscillator. The modulating signal is applied via an amplifier valve (V4), the SET CARRIER control (RV2), and an r.f. filter, to the anode of the oscillator valve (V9).

1.2.3 Fine Tuning and Incremental Frequency Controls.

The FINE TUNING control is a variable resistor (RV22) in series with the h.t. feed to the modulator-driver valve (V8). Adjustments to the control produce variations in the anode and screen-grid voltages of V8, and thus alter the standing current in the l.f. winding of the ferrite modulator. This action, of course, alters the carrier frequency of the oscillator.

The INCremental FREQuency controls - i.e., the switch and the continuously variable control - also vary the standing current in the l.f. winding of the modulator. However, in this case, the effect is produced by varying the level of a d.c. voltage applied to the correcting network in the grid circuit of the driver valve (V8).

1.2.3 (continued)

The INC. FREQ. switch (SE) has eight positions, viz., a central zero position, three positive and three negative shift positions, and a position engraved VAR. The positive and negative shift voltages are derived from separate miniature pre-set potentiometers (RV15 to RV20), and the continuously-variable shift voltage is derived via variable potentiometer RV23. In all cases the shift voltage is monitored on the MODULATION AND INCREMENTAL FREQUENCY meter, M1, whose two incremental scales are calibrated directly in kc/s of frequency shift.

1.2.4 Modulation and Incremental Frequency Monitor.

The MODULATION AND INCREMENTAL FREQUENCY meter is used for monitoring the f.m. deviation, the incremental frequency shift, and also the a.m. depth. The setting of the monitor-selector switch (SF) determines whether the meter shall indicate the amount of modulation or incremental-frequency shift. This switch can also be set to give a choice of two sensitivities for either of these functions.

When the meter is used for monitoring incremental shift, it acts as a simple d.c. voltmeter connected between the slider of the continuously-variable incremental frequency control and chassis.

The operation of the modulation monitoring system can be most easily understood by considering the amplitude-modulation monitor first. When the carrier is amplitude modulated, the r.f. monitoring detector (MR6) produces an output which contains an a.f. component in addition to the d.c. component that produces the deflection of the CARRIER LEVEL meter pointer. This a.f. component is fed via a.d.c. blocking capacitor (C47) to the grid of the first triode section of double-triode valve V10. This first section is connected as a simple R-C coupled amplifier; the output of this amplifier is fed to the second triode section, which is connected as a cathode follower. The output from the cathode follower is rectified by germanium diodes MR4 and MR5 and passed to the monitoring meter (M1). Diodes MR4 and MR5 are connected in the form of a voltage-doubler circuit; this arrangement gives an improved scale linearity and better sensitivity than a single-diode detector. The monitor reads half of the peak-to-peak value of the waveform.

When the Signal Generator is set for frequency modulation, the grid of the cathode-follower section of V10 is disconnected from the R-C amplifier by the action of the modulation-selector switch (SD);

1.2.4 (continued)

and it is then coupled to the input of the correcting network to the modulator-driver valve (V8). In this way the level of the audio-frequency signal applied to the network is monitored. The correcting network is automatically adjusted to keep the ratio of a.f. input voltage to f.m. deviation constant at all carrier frequencies. The meter, therefore, gives a correct reading of f.m. deviation at all settings of the tuning controls.

1.2.5 Power Supply Unit

The mains transformer (T2), which forms part of the built-in power unit, has a primary winding consisting of two tapped sections. These sections permit a series or series-parallel arrangement in order to cover input ranges of 100 to 130 volts and 200 to 250 volts, at 40 to 60 cycles. Voltage adjustments are made by means of a plug-in type panel that is accessible from the right-hand case-handle recess. Instructions for making the necessary adjustments to suit different supply voltages are contained in Section 4.3.

The main h.t. supply is derived from a low-impedance series-stabilizer circuit comprising valves V3 and V5 with a reference potential controlled by the gas-filled stabilizer V6. The input for this circuit is drawn, via a full-wave rectifier (V2), from a centre-tapped h.t. winding on the mains transformer. A negative reference voltage for the incremental frequency controls is obtained from a full-wave rectifier circuit containing MR3 and MR7, the a.c. being drawn from the tapped h.t. secondary winding on the mains transformer. The reference voltage is regulated by means of a gas-filled stabilizer (V7).

The heater supply for the r.f. oscillator and modulator-driver valves is derived from winding LT4 on the mains transformer, via a series stabilizer circuit utilizing transistors. In the stabilizer, VT3 is the series regulator in the negative line, and it is fed by a d.c. amplifier (VT1) via an emitter-follower (VT2). The reference voltage for VT1 is obtained from a variable potentiometer (RV4) across the regulated h.t. supply. The heater supplies for the other valves in the instrument are obtained directly from LT1, LT2, and LT3 windings.

# 2 OPERATION

## 2.1 INSTALLATION

Signal Generator Type TF 1066B can be adjusted for operation from any 40-c/s to 60-c/s mains supply in the voltage ranges 100 to 130 volts and 200 to 250 volts.

Full instructions for adjusting the internal power unit to suit the local supply are given in Section 4.3.

Unless otherwise specified, the Signal Generator is normally despatched ready for immediate operation from 240-volt, 40-c/s to 60-c/s supplies.

## 2.2 SWITCHING ON

Be sure that the instrument is correctly adjusted to suit the particular mains supply to which it is to be connected. Then proceed as follows:-

(1) Connect the mains lead to a supply socket. The lead is permanently attached to the instrument and is stowed in the left-hand case-handle recess.

(2) Switch ON by means of the SUPPLY switch, when the red pilot lamp should glow.

Before proceeding further, wait two or three minutes for the valves and internal circuits to warm up. If a reasonable order of stability is required, extend this period to about half an hour, or for the full rated stability, to a few hours.

## 2.3 TUNING

The Signal Generator covers its carrier range in five bands:-

10 to 22 Mc/s
22 to 48 Mc/s
48 to 110 Mc/s
110 to 240 Mc/s
240 to 470 Mc/s

2.3 (continued)

The tuning facilities are as follows:-

(1) The output signal can be set by means of the COARSE TUNING control to any predetermined frequency as read directly from the main tuning dial (see Section 2.3.1).

(2) The FINE TUNING control enables the operator to tune the Signal Generator precisely to a desired point on the response characteristic of the equipment under test (see Section 2.3.1).

(3) The continuously variable incremental-frequency control can be used for shifting the carrier frequency by known amounts up to 100 kc/s in either direction (see Section 2.3.2).

(4) The INCremental FREQuency switch may be used for shifting the carrier frequency in six pre-set steps up to a maximum shift of 100 kc/s in either direction (see Section 2.3.3).

(5) Incremental frequency shifts can also be produced by means of an external circuit coupled to the external modulation f.m. terminals. This facility can be used for the production of carrier shifts of up to 100 kc/s in either direction (see Section 2.3.4).

2.3.1 General Procedure

To tune the Signal Generator to a particular frequency proceed as follows:-

(1) Set the INC FREQ switch to its central 'zero' position, and the FINE TUNING control to mid travel.

(2) Select the required frequency band by means of the RANGE control. To change from one band to another rotate the control through one-and-a-fifth turns per band until it locates positively with the knob pointing to the required frequency band.

(3) By means of the COARSE TUNING control, tune the Signal Generator to the required carrier frequency as indicated on the main tuning dial. Using the hairline on the transparent cursor, read the frequency on the calibration arc appropriate to the band selected in (2) above.

2.3.1 (continued)

Fine Tuning. To tune the Signal Generator precisely to a particular point on the characteristic of a tuned system under test (e.g., to peak the tuning to the centre frequency of a receiver's response) proceed as follows:-

(1) Use the COARSE TUNING control to bring the signal frequency as near to the required point as possible.

(2) Make the final adjustment with the FINE TUNING control. The total cover of this control is of the order of 25 kc/s.

2.3.2 The Continuously Variable Incremental-Frequency Control.

(1) Set the INC FREQ switch to VAR and the monitor-selector switch to INC FREQ 20 kc/s.

(2) Adjust the continuously variable incremental-frequency control to bring the pointer of the MODULATION AND INCREMENTAL FREQUENCY meter to the centre-zero mark on the lowest scale of the dial.

(3) Use the COARSE TUNING control to tune the Signal Generator to the approximate centre frequency of the equipment under test, and set up for c.w. or a.m. as described in Sections 2.4.1 and 2.4.4. Response or bandwidth measurements are not normally made with a frequency-modulated signal.

(4) If, in (3) above, the monitor-selector switch has been turned to a MOD position, restore it to one of its INC FREQ positions - either 20 kc/s or 100 kc/s depending on the range over which the incremental frequency variations are to be made.

(5) Use the COARSE and FINE TUNING controls to tune the Signal Generator accurately to the centre frequency of the equipment under test.

(6) Adjust the continuously variable incremental-frequency control to produce the required change in carrier frequency. Read the change in frequency directly from the appropriate scale of the MODULATION AND INCREMENTAL FREQUENCY meter. The incremental scales are easily identified being marked in red on the lowest arc of the meter dial. If necessary, apply the correction for accuracy - see under.

2.3.2 (continued)

Accuracy of Incremental-Frequency Meter. For carrier frequencies between 10 and about 240 Mc/s, the meter indication is accurate to within 10% of full scale for all values of shift up to the maximum of 100 kc/s.

At higher carrier frequencies the accuracy of the meter indication falls off to 20%, but an accuracy of 10% of full scale can be obtained by applying the correction given by the black curve on the CORRECTION CHART FOR DEVIATION AND INCREMENTAL FREQUENCY MONITOR. This chart is in the form of a card and is normally stowed in the left-hand case-handle recess.

2.3.3 The Stepped Incremental-Frequency Switch

When the instrument leaves the factory, its incremental steps are set to zero shift, since the user will wish to set increments of his own choice.

To set up the incremental steps, see part B of Section 4.9.9.

(1) Set the INC FREQ switch to its zero position.

(2) Use the COARSE TUNING control to tune the Signal Generator to the approximate centre frequency of the equipment under test, and set up for c.w. or a.m. as described in Sections 2.4.1 and 2.4.4.

(3) Tune the Signal Generator accurately to the centre frequency of the equipment under test using the COARSE and FINE TUNING controls.

(4) Use the INC FREQ switch to shift the carrier frequency in the positive or negative pre-set steps as required.

Stepped increments are indicated by the monitor meter with the same accuracy as for continuously variable control. For greater accuracy the steps can be set up against a standard-frequency r.f. source.

WARNING: Inaccuracies due to external circuits. If the circuit of any apparatus connected to the EXT MOD F.M. and earth terminals offers a d.c. path, the potentiometer network controlled by the INC FREQ switch will be shunted and the accuracy of the incremental frequency steps will be affected. This may be avoided by the insertion of a capacitor in the lead used to make connection to the EXT MOD F.M. terminal.

2.3.4 Frequency Shift From an External Source

Incremental frequency shifts can be produced by the application of an external d.c. voltage between the EXT MOD F.M. and earth terminals when the INC FREQ switch is set to VAR. This may be useful for the production of stepped frequency shifts if the required steps are other than these already pre-set and it is desired not to disturb the pre-set steps.

The method of using this external shift facility is described below :-

(1) Connect the external d.c. circuit to the EXT MOD F.M. and earth terminals.

(2) Set the INC FREQ switch to VAR and the continuously variable control to mid travel. Do not move the control again during the test.

(3) Set the monitor-selector switch to INC FREQ 20 or 100 kc/s according to the maximum incremental frequency shift to be used.

(4) Set up the external incremental steps, starting with the lowest values of shift, and setting up the highest values last. A d.c. voltage of approximately 60 volts is required for a shift of 100 kc/s.

See last part of Section 2.3.2. - Accuracy of Incremental Frequency Meter.

2.3.4 (continued)

(5) Having initially set up the external shifts, tune the Signal Generator in the normal manner, as described in Section 2.3.1

In order to preserve the accuracy of the internal incremental frequency steps, the external d.c. shift circuit should be removed from the EXT. MOD. F.M. terminals when it is not in use - see last part of Section 2.3.3.

2.3.5 Modulator Hysteresis

When making incremental-frequency shifts by any of the methods described in the preceding sections, the operator may find some inconsistency of results due to inherent hysteresis in the ferrite modulator.

The effects of this hysteresis are only of significance when the operator makes a frequency shift in a direction different from that previously applied, i.e., when the shift is (i) changed from a positive to a negative value, or vice versa, or (ii) decreased to, or towards, zero. If the shift is increased to a particular value from the true (neutralized) zero, and then further increased, the hysteresis problem does not arise.

Errors due to hysteresis will generally be small - of the order of 5% of the shift - and can be eliminated by 'wiping' or neutralizing the magnetic circuit of the modulator before making a reversal of frequency shift. As a point of good practice, this neutralizing should also be carried out before commencing any measurements involving use of the incremental-frequency controls.

2.3.5 (continued)

To neutralize modulator hysteresis, first set the incremental shift to zero and apply f.m. to the carrier; then, having set deviation initially to maximum, reduce it slowly to zero. With the modulator now neutralized it may be advisable to check that the Signal Generator is still correctly tuned to the centre frequency of the equipment under test; if necessary, make slight adjustments to the COARSE and/or FINE TUNING controls.

The following example shows the points in a typical sequence of incremental shifts at which it is desirable to neutralize the modulator:

Example: In a receiver response investigation, it is required to shift carrier + 50, + 75, + 100 kc/s; then to drop back in frequency and recheck results at + 50 kc/s.

Do this by (i) neutralizing at zero shift; (ii) setting to + 50 kc/s; (iii) setting to + 75 kc/s; (iv) setting to + 100 kc/s; (v) returning to zero and neutralizing again; (vi) setting to + 50 kc/s.

## 2.4 SETTING UP FOR CONTINUOUS WAVE OR MODULATED OUTPUTS

The r.f. output from the Signal Generator can be

(i) Continuous Wave - see Section 2.4.1
(ii) Frequency Modulated - see Section 2.4.3
(iii) Amplitude Modulated - see Section 2.4.4

### 2.4.1 Continuous Wave

(1) Set the modulation-selector switch to C.W.

(2) Tune to the desired frequency in the manner described earlier in Section 2.3.1.

(3) Turn the ATTENUATOR control to bring the dial to the required setting. (A detailed explanation of the method of setting the r.f. output voltage is given in Section 2.5. R.F. OUTPUT ARRANGEMENTS).

(4) Adjust the SET CARRIER control to bring the pointer of the CARRIER LEVEL meter to the SET CARRIER mark.

### 2.4.2 Precautions Against Spurious Modulation

Although every effort has been made to produce a design giving freedom from microphony, it is not possible to eliminate this type of spurious modulation altogether. The user is therefore advised to take normal precautions for preventing the excitation of modulation due to microphony.

For example, if the Signal Generator is to be used for signal-to-noise ratio or similar measurements where spurious modulation is particularly undesirable, it is an advantage to stand it on a sponge-rubber or felt mat. If the receiver delivers a high a.f. output, its loudspeaker should be directed away from the Signal Generator, or - better still - disconnected.

### 2.4.3 Frequency Modulation

The accuracy of the deviation indication and the wave form of the demodulated signal may tend to deteriorate slightly when carrier shift is applied by means of the INC FREQ controls. It is generally advisable, therefore, to keep the INC FREQ switch in its zero position when using frequency modulation.

(A) Internal F.M.

(1) Set the modulation-selector switch to INT F.M.

(2) Tune the Signal Generator, and adjust the ATTENUATOR and SET CARRIER controls to produce the required output in a manner similar to that described for c.w. operation.

(3) Set the monitor-selector switch to MOD 0-20 or MOD 0-100 depending on the deviation to be used.

(4) Set the MOD FREQ toggle switch to 1 kc/s or 5 kc/s according to the modulation frequency required.

(5) Adjust the SET MOD control to bring the pointer of the MODULATION AND INCREMENTAL FREQUENCY meter to the required deviation indication.

2.4.3 (continued)

Monitor Accuracy. At carrier frequencies below 110 Mc/s, the deviation indication is accurate to within 7% of full-scale deflection.

Between 110 Mc/s and 240 Mc/s, the indication is generally accurate to within 7% of f.s.d. but may fall outside this tolerance at certain frequencies in the band. A curve giving the correction for deviation against carrier frequency over the range 110 to 240 Mc/s is shown in red on the CORRECTION CHART FOR DEVIATION AND INCREMENTAL FREQUENCY MONITOR; this chart is in the form of a card and is normally stowed in the left-hand case-handle recess.

Above 240 Mc/s, the deviation accuracy falls to 20% of f.s.d. but an accuracy of 7% of f.s.d. can be obtained by applying the correction given by the black curve on the chart.

A.F. Synchronizing Signal. When the modulation selector is set to INT F.M., the internal modulating signal is available at the EXT MOD F.M. and earth terminals. It may be used as a convenient synchronizing signal when the Signal Generator is used in conjunction with a cathode-ray oscilloscope. At the maximum deviation of 100 kc/s, the level of this signal is of the order of 20 volts r.m.s. - see WARNING at the end of Sect. 2.3.3.

(B) External F.M.

(1) Set the modulation-selector switch to EXT F.M.

(2) Connect the external a.f. signal source to the EXT MOD F.M. and earth terminals - see WARNING at end of Sect. 2.3.3.

(3) Tune the Signal Generator and adjust the ATTENUATOR and SET CARRIER controls to produce the required output in a manner similar to that for c.w. operation.

(4) Set the monitor-selector switch to MOD 0-20 or MOD 0-100 depending on the deviation to be used.

2.4.3 (continued)

(5) Adjust the level of input from the external source to bring the pointer of the MODULATION AND INCREMENTAL FREQUENCY meter to the required deviation mark on the scale appropriate to the setting of the monitor-selector switch; apply the necessary correction to the meter reading for carrier frequencies above 110 Mc/s.

The impedance presented at the EXT F.M. and earth terminals to the external modulating source is nominally 5 kΩ. An input of the order of 20 volts is required to produce the maximum deviation of 100 kc/s. The deviation monitor is accurate to within ±5% of the accuracy at 1 kc/s over the range 30 c/s to 15 kc/s.

2.4.4 Amplitude Modulation

(A) Internal A.M.

(1) Set the modulation-selector switch to INT A.M. and turn the SET MOD control fully counter-clockwise.

(2) Tune the Signal Generator and adjust the ATTENUATOR and SET CARRIER controls to produce the required output level in a manner similar to that described for c.w. operation.

(3) Set the monitor-selector switch to MOD 0-20 or MOD 0-100 depending on the depth of modulation to be applied.

(4) Set the MOD FREQ toggle switch to 1 kc/s or 5 kc/s according to the modulation frequency required.

(5) Advance the SET MOD control until the pointer of the MODULATION AND INCREMENTAL FREQUENCY meter indicates the required modulation depth on the scale appropriate to the setting of the monitor-selector switch. The movement of the SET MOD control may cause a change in the deflection of the CARRIER LEVEL meter pointer; do not re-adjust the SET CARRIER control to bring the pointer back to the SET CARRIER mark.

2.4.4(continued)

Monitor Accuracy. On the 0-20 range of the modulation monitor, the modulation-depth indication is accurate to within 2% modulation. On the 0-100 range, the indication is accurate to within 5% modulation up to 40%. Although the specified maximum modulation depth for the TF 1066B is 40%, modulation depths considerably greater than this can generally be obtained. Nevertheless, the specified maximum modulation depth should be borne in mind, and the modulation-depth indication should not be regarded as valid above 40%.

A.F. Synchronizing Signal. When the modulation selector switch is in the INT A.M. position, the 1-kc/s or 5-kc/s input to the modulation amplifier is also applied to the EXT MOD A.M. and earth terminals. It may be used as a convenient synchronizing signal when the Signal Generator is used in conjunction with a cathode-ray oscilloscope. At 40% modulation depth, the level of this signal is of the order of 10volts r.m.s.

(B) External A.M.

(1) Set the modulation-selector switch to EXT A.M.

(2) Tune the Signal Generator and adjust the ATTENUATOR and SET CARRIER controls to produce the required output in a manner similar to that described for c.w. operation.

(3) Set the monitor-selector switch to MOD 0-20 or MOD 0-100 depending on the modulation depth to be applied.

(4) Connect the external a.f. source to the EXT MOD A.M. and earth terminals; and adjust the input level until the pointer of the MODULATION AND INCREMENTAL FREQUENCY meter indicates the required modulation depth on the scale appropriate to the setting of the monitor-selector switch. If this action causes a change in the deflection of the CARRIER LEVEL meter, do not readjust the SET CARRIER control to bring the pointer of the meter back to the SET CARRIER mark.

2.4.4 (continued)

The impedance presented at the EXT A.M. and earth terminals to the external modulating source is nominally 1 MΩ shunted by 20 pF. An input of the order of 10 volts is required to produce 40% modulation depth. Between 30 c/s and 15 kc/s the amplitude-frequency characteristic of the modulating circuit is flat to within 1 dB relative to the response at 1 kc/s.

## 2.5 R.F. OUTPUT ARRANGEMENTS

For consideration of its output circuit, the TF 1066B can be regarded as a zero-impedance voltage generator in series with a resistance of 50 ohms. This condition is shown diagrammatically in figure 1 of drawing No. TLC 28189, where E is the source e.m.f., $R_O$ is the source impedance of the Signal Generator, $Z_L$ is the load impedance, and $V_L$ is the voltage actually developed across the load.

The Attenuator Dial. This dial has two scales: one is calibrated from -14 to + 106 and denotes the output in decibels relative to 1 μV; the other is calibrated directly in units of voltage.

With the SET CARRIER control adjusted to bring the CARRIER LEVEL meter pointer to the SET CARRIER mark, the attenuator scales are direct reading, each in its particular units as described in the previous paragraph.

The Reversible Cursor. The transparent cursor fitted to the attenuator dial is reversible and is engraved with two hairlines, one vertical and one inclined at an angle corresponding to a 6-dB movement of the dial.

On one side of the cursor, the inclined hairline is marked E.M.F. FROM 50 OHM SOURCE and the vertical hairline is marked -6 dB. When the cursor is fitted with this side showing, the inclined hairline indicates the output level in terms of source e.m.f. (E in figure 1 of TLC 28189). The dial reading at the vertical hairline is the effective source e.m.f. when the 6-dB Attenuator Pad Type TM 4919/1 is in use. (See Section 2.5.1).

On the other side of the cursor, the vertical hairline is marked VOLTS INTO 50 OHM LOAD and the inclined hairline is marked -6 dB. when the cursor is fitted with this side showing, the output level i indicated by the vertical hairline is in terms of the potential ($V_L$ in figure 1 of TLC 28189) developed across a 50-ohm load connected to the r.f. outlet of the Signal Generator. The dial indication at the inclined hairline is the voltage appearing across a 50-ohm load when the 6-dB Pad is in circuit.

2.5 (continued)

To reverse the cursor:-

(1) Extract the centre screw securing the transparent plastic window of the attenuator dial.

(2) Remove the window and take off the spun-metal cover and spring at the centre of the dial.

(3) Lift out the cursor, turn it over, and replace it.

(4) Replace the spring, the spun cover, and the transparent window, and secure them in position with the centre screw.

2.5.1 Output Accessories

OUTPUT CONNECTOR Type TM 4824. This is a 50-ohm coaxial cable 30 inches long and fitted at either end with a standard type N free plug (Great Britain, Transradio Ltd. type GE.071: United States, Military No. UG-21B/U). These plugs mate with either standard type N free sockets (Great Britain, Transradio Ltd. type 6.043; United States, Military No. UG-23B/U) or panel mounting type N sockets (Great Britain, Transradio Ltd. type DE.071; United States, Military No. UG-22B/U).

20-dB ATTENUATOR PAD Type TM 4919. This is a conventional $\pi$-section attenuator pad with 20-dB insertion loss. The input resistance and output resistance are each 50 ohms. The applications of this pad are dealt with in Section 2.5.2, which follows. It is fitted with a type N socket at its input end and a type N plug at its output end.

6-dB ATTENUATOR PAD Type TM 4919/1. This pad has an insertion loss of 6 dB but is otherwise similar to the 20-dB Pad Type TM 4919.

50-OHM to 75-OHM MATCHING UNIT Type TM 4918. For details of the electrical action of this unit, refer to Section 2.5.2(c). When fitted, it converts the effective source impedance of the Signal Generator from 50 ohms to 75 ohms. The Matching Unit is fitted with a Type N socket at its input end and a Belling Lee plug Type L734/P at its output end; this plug mates with a Belling Lee free socket Type L734/J or panel-mounting socket Type L604/S.

2.5.1 (continued)

50-OHM to 300-OHM UNBALANCE TO BALANCE TRANSFORMER Type TM 4916. The electrical action of this unit is described in Section 2.5.2(d), and it is used when the output of the Signal Generator is applied to a balanced-winding input circuit. The unit gives a line-to-line source impedance of 300 ohms. It contains resistive elements only and is not suitable for matching into balanced input circuits which are not in the form of windings. It is fitted with a Type N socket at its input end and solder spills at its output end.

D.C. ISOLATING UNIT Type TM 4917. This unit contains a 300-volt-working 0.001-μF capacitor connected in series with the output line so that the Signal Generator may be connected to a point of high d.c. potential on the equipment under test. The Isolating Unit is fitted with a Type N socket at its input end and two crocodile clips at its output end.

COAXIAL FUSE Type TM 5753. This unit is connected in series with the Signal Generator output; it prevents damage to the instrument's attenuator through accidental application of r.f. or h.t. power to the circuit under test. For characteristics, see Schedule of Parts Supplied, page vi.

2.5.2 Coupling to the Equipment Under Test

The output impedance of the Signal Generator is nominally equal to the characteristic impedance of the Connector cable. This cable may therefore be regarded as correctly terminated at its input end; serious errors in the apparent e.m.f. caused by standing waves on the cable can therefore generally be neglected even when the input impedance of the equipment under test is not equal to 50 ohms.

However, it is often important for other reasons that the source impedance is accurately matched to the load or that it has a particular known value not equal to 50 ohms. Under these circumstances, the source impedance at the output end of the system can be altered to the required value by the use of various matching networks. The paragraphs which follow give details of the various methods of coupling the Signal Generator via a selection of resistive impedance-correcting networks.

2.5.2 (continued)

(a) Coupling from the 50-ohm Source

When the equipment under test has an input impedance other than 50 ohms and it is important that the signal is derived via a 50-ohm resistive source impedance, it is advisable, if the insertion loss can be tolerated, to couple the output Connector to the equipment via the 50-ohm 20-dB Attenuator Pad.

With the Pad in circuit, the possibility of error in apparent e.m.f. or effective output impedance due to standing waves is avoided because it is impossible to mis-match the cable seriously - variations in the load impedance from zero to infinity cause the effective line-terminating resistance to depart from its correct value by only 1 ohm approximately.

Figure 2 on Drawing No. TLC 28189 (following page 24) shows diagrammatically the effect of connecting the Pad into circuit. The final output conditions are equivalent to those of a zero-impedance generator producing an e.m.f. equal to E/10 in series with a resistance, $R_{EO}$, of 50 ohms. The p.d. across the load can, of course, be calculated in the usual way and is equal to

$$\frac{E}{10} \times \frac{Z_L}{R_{EO} + Z_L}$$

where E is the e.m.f. indicated on the Attenuator dial.

$R_{EO}$ is the effective source resistance of the Signal Generator (50 ohms)

$Z_L$ is the input impedance of the equipment under test.

If, however, the insertion loss of the 20-dB Pad cannot be tolerated, the 6-dB Attenuator Pad may be used instead. Although this Pad does not isolate the Signal Generator impedance from the load to the same degree as its 20-dB counterpart, it will usually be effective enough for all normal applications.

The final output conditions with the 6-dB Pad connected are equivalent to those of a zero-impedance generator producing an e.m.f. equal to E/2 in series with a resistance of 50 ohms. The p.d. across the load, is of course, equal to

$$\frac{E}{2} \times \frac{Z_L}{R_{EO} + Z_L}$$

2.5.2 (continued)

(b) Source Resistance Less Than 50 ohms.

If the required source resistance is less than 50 ohms, the arrangement shown in figure 3 of TLC 28189 can be used. The resistance $R_p$ is effectively in parallel with the source resistance of the Signal Generator so that the output resistance of the system, $R_{EO}$, is given by the standard expression for resistance in parallel, viz:

$$R_{EO} = \frac{R_p \times R_O}{R_p + R_O}$$

where $R_O$ is the output resistance of the Signal Generator.

Since the required output resistance is usually the known term, the above expression is more useful when rearranged as follows:-

$$R_p = \frac{R_O \times R_{EO}}{R_O - R_{EO}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Under these conditions, the effective source e.m.f., $E_{EFFECT}$, presented to the load is given by the expression

$$E_{EFFECT} = E \times \frac{R_p}{R_p + R_O} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where E is the e.m.f. indicated on the attenuator dial.

(c) Source Resistance Greater Than 50 ohms.

If the required source resistance is greater than 50 ohms, a resistor having a value $R_s$ can be connected in series with the output as shown in figure 4 of TLC 28189. With this arrangement, the effective output resistance, $R_{EO}$, is given by the expression for resistances in series, viz:

$$R_{EO} = R_O + R_s$$

or, more conveniently,

$$R_s = R_{EO} - R_O \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where $R_O$ is the output impedance of the Signal Generator.

2.5.2 (continued)

For the special case where $R_{EO}$ is equal to 75 ohms, the 50-ohm to 75-ohm Matching Unit Type TM 4918 is available. This unit contains a 25-ohm resistor which, connected in series with the 50-ohm source resistance of the Signal Generator, gives an effective output resistance of 75 ohms.

When the effective output resistance is altered by either of the above methods, the Connector is mismatched at its output end. It is therefore advisable, if the insertion loss can be tolerated, to insert the 20-dB Pad or the 6-dB Pad between the output end of the Connector and the correcting resistor $R_p$ or $R_c$. The effective source e.m.f. and p.d. across the load are, of course, then reduced by a factor of 20 dB or 6 dB.

(d) Using the Signal Generator with Balanced Loads.

With certain types of equipment, the input circuit is in the form of a balanced winding. Such equipment can be fed from the unbalanced output of the Signal Generator via two correcting resistors as shown in figure 5 of Diagram No. TLC 28189; this arrangement makes use of the auto-transformer effect of the centre-tapped winding to simulate the behaviour of a balanced source. One resistor, $R_{s1}$, is connected in series between the earthed screen of the output accessory in use and one side of the balanced winding, and a second resistor, $R_{s2}$, is connected in series with the 'live' output connection and the other side of the balanced winding.

The values of the two resistors, $R_{s1}$, and $R_{s2}$, can be calculated from the following expressions:

$$R_{s1} = \frac{R_{EO}}{2}$$

$$R_{s2} = \frac{R_{EO}}{2} - R_O \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where $R_{EO}$ is the required line-to-line output resistance of the Signal Generator

$R_O$ is the source resistance of the Signal Generator (50 ohms).

2.5.2 (continued)

The 50-ohm to 300-ohm Unbalance to Balance Transformer type TM 4916 operates on the principle described above.

When feeding balanced loads by the method described above, it is advisable, if the insertion loss can be tolerated, also to include the 20-dB Pad or the 6-dB Pad. The effective source e.m.f. is, of course, then reduced by a factor of 20 dB or 6 dB.

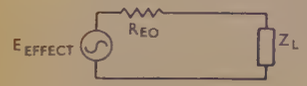
# OUTPUT ARRANGEMENT DIAGRAMS

| MARCONI INSTRUMENTS LIMITED | | | | | | | |
|---|---|---|---|---|---|---|---|
| DRN | D H | DATE | 4 58 | CHKD | M C. | ISSUE | 2 |
| STOCK LIST | | | | DRG No. | TLC 28189 | | |

E IS THE E.M.F. INDICATED ON THE ATTENUATOR DIAL
$R_O$ IS THE OUTPUT RESISTANCE OF THE GENERATOR = 50 OHMS
$V_L$ IS THE P.D. ACROSS THE LOAD
$Z_L$ IS THE LOAD IMPEDANCE

FIGURE 1 OUTPUT CONDITIONS FOR DIRECT COUPLING

OUTPUT CIRCUIT WITH 6-dB OR 20-dB PAD IN USE




THIS IS EQUIVALENT TO:—
WHERE $E_{EFFECT} = \frac{E}{2}$ FOR 6-dB PAD
OR $\frac{E}{10}$ FOR 20-dB PAD
$R_{EO} = R_O$

FIGURE 2
OUTPUT CONDITIONS FOR COUPLING VIA AN ATTENUATOR PAD

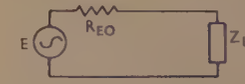
OUTPUT CIRCUIT FOR SOURCE RESISTANCE < 50 OHMS

THIS IS EQUIVALENT TO:—
WHERE $E_{EFFECT} = E \frac{R_P}{R_P + R_O}$
$R_{EO} = \frac{R_P R_O}{R_P + R_O}$

FIGURE 3 OUTPUT CONDITIONS USING PARALLEL RESISTOR

OUTPUT CIRCUIT FOR SOURCE RESISTANCE > 50 OHMS

THIS IS EQUIVALENT TO:—

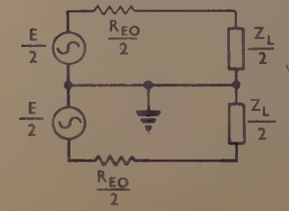



WHERE $R_{EO} = R_O + R$

FIGURE 4 OUTPUT CONDITIONS USING SERIES RESISTOR

OUTPUT CIRCUIT FOR BALANCED LINE-TO-LINE SOURCE RESISTANCE < 100 OHMS

WHEN FEEDING INTO BALANCED WINDING THIS IS EQUIVALENT TO:—




WHERE $R_{EO}$ = LINE-TO-LINE RESISTANCE

$R_O + R_{S2} = \frac{R_{EO}}{2}$

$R_{S1} = \frac{R_{EO}}{2}$

FIGURE 5
OUTPUT CONDITIONS FOR COUPLING TO BALANCED WINDING

## 3 OPERATIONAL SUMMARY

When the user is familiar with the principles and techniques of operation detailed in Section 2, the following abridged instructions may be found a convenient guide for quick reference.

Frequency Range: 10 to 470 Mc/s

Source Impedance: 50 ohms

Open-Circuit Output Voltage: 0.2 µV to 200 mV

Modulation: F.M. up to 100 kc/s; can also be amplitude modulated

Frequency Shift: variable up to ±100 kc/s

Power Supply: 100 to 150 volts, 40 to 60 c/s;
180 to 250 volts, 40 to 60 c/s.

Be sure that the power unit is correctly adjusted before switching the instrument on.

For further details, refer to Section 4.3.

### TUNING

GENERAL: Set INC FREQ switch to its central-zero position.
Set RANGE switch to required band.
Use COARSE TUNING control to bring main tuning dial to required frequency.
Peak tuning to desired point on receiver response by means of FINE TUNING control.

For further details, refer to Section 2.3.1.

3 (continued)

INCREMENTAL FREQUENCY ADJUSTMENTS

Variable Control: Set INC FREQ switch to VAR.
Set monitor selector to INC FREQ 20 kc/s or INC FREQ 100 kc/s.
Adjust incremental-frequency control to centralise pointer of MODULATION AND INCREMENTAL FREQUENCY meter. Tune to centre frequency of receiver by means of COARSE and FINE TUNING controls. Adjust incremental frequency control to produce required carrier shift as indicated by meter.

For further details refer to Section 2.3.2.

INC. FREQ. Switch: Set INC FREQ switch to its central zero position.
Tune to centre frequency of receiver under test by means of COARSE and FINE TUNING controls.
Use INC FREQ switch to produce required carrier shift.

For further details refer to Section 2.3.3.

SETTING UP FOR C.W. OR MODULATED OUTPUT

C.W.: Set modulation selector to C.W.
Adjust SET CARRIER control to bring pointer of CARRIER LEVEL meter to its SET CARRIER mark.

For further details see Section 2.4.1.

FREQUENCY MODULATION

Internal: Set modulation selector to INT F.M.
Set monitor selector to MOD 0-100 or MOD 0-20.
Adjust SET MOD control to bring pointer of MODULATION AND INCREMENTAL FREQUENCY meter to required reading.

For further details see Section 2.4.3.

External: Set modulation selector to EXT F.M.
Connect modulating source to EXT MOD F.M. and earth terminals.
Set monitor selector to MOD 0-100 or MOD 0-20.

3 (continued)

Adjust level of external source to bring pointer of the MODULATION AND INCREMENTAL FREQUENCY meter to required reading.

For further details see Section 2.4.3.

AMPLITUDE MODULATION

Internal: Set modulation selector to INT A.M.
Set monitor selector to MOD 0-100 or MOD 0-20.
Adjust SET MOD control to bring pointer of MODULATION AND INCREMENTAL FREQUENCY meter to required reading.

For further details see Section 2.4.4.

External: Set modulation selector to EXT A.M.
Connect external modulating source to EXT MOD A.M. and earth terminals.
Set monitor selector to MOD 0-100 or MOD 0-20.
Adjust level of external source to bring pointer of MODULATION AND INCREMENTAL FREQUENCY meter to required reading.

For further details see Section 2.4.4.

SETTING R.F. OUTPUT LEVEL

ATTENUATOR DIAL:

Adjust ATTENUATOR control to produce (i) a dial indication of required output e.m.f. or (ii) an indication of required p.d. across a 50-ohm load connected to R.F. OUTPUT socket. Type of indication depends upon position of cursor.

For details see Section 2.5.

# 4 MAINTENANCE

## 4.1 GENERAL

The following items are included in this handbook to assist in the maintenance of the FM Signal Generator Type TF 1066B :-

Functional Diagram
Complete Circuit Diagram
Valve Replacement Data Sheets

Section 1, DESCRIPTION, of this handbook deals with the internal circuits of the Signal Generator and is intended to be read in conjunction with the Circuit and Functional Diagrams included at the end of this manual. It is strongly recommended that, before commencing the adjustment or replacement of component parts of the instrument, the user should familiarize himself with the principles described in Section 1 and illustrated in the diagrams.

The Circuit Diagram shows all the electrical components contained in the instrument. The descriptions of these components - their values and ratings, etc. - are given in the Component List.

## 4.2 REPLACEMENT OF FUSES

The mains-input and h.t. circuits of the TF 1066B are protected by five cartridge fuses; two 2-amp in the supply lines, two 1-amp in the regulated l.t. line and a 250-mA in the mains transformer h.t. centre tap line. The mains and h.t. fuses are located in the right-hand case-handle recess and can be replaced without removing the instrument from its case. The l.t. fuses are located in clips on the underside of the l.f./power unit chassis, close to the mains transformer.

## 4.3 MAINS INPUT ARRANGEMENTS

### 4.3.1 General

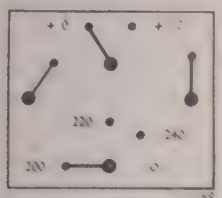
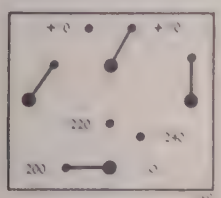
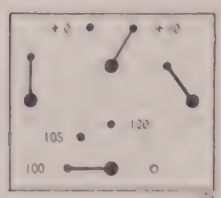
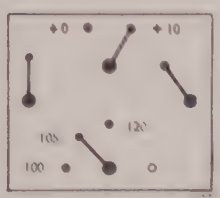
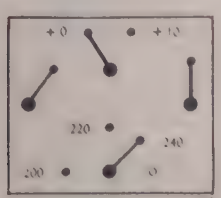
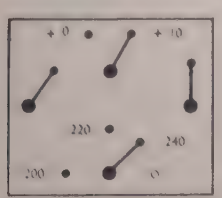
The instrument can be adjusted to operate from any supply within the ranges 100 to 150 volts and 200 to 250 volts, 40 to 60 c/s.

The mains transformer has two tapped primary windings to permit series or series-parallel arrangement in order to cover the input ranges of 100 to 130 volts and 200 to 250 volts, at 40 to 60 cycles. Voltage adjustments are made by means of four two-pin plugs that make contact with the connections to the transformer through a reversible masking plate. This plate is marked on one side with voltages applicable to the 200- to 250-volt range (white figures), and on the other side with voltages applicable to the 100- to 130-volt range (black figures). All the possible combinations to suit the input ranges covered by the instrument are shown in the SUPPLY VOLTAGE PLUG SETTINGS illustration that follows this page.

To make an adjustment to the voltage adjusting panel, first, remove the cover plate in the right-hand case-handle recess. After this cover has been removed, the reversible masking plate and the four plugs are immediately accessible.

## SUPPLY VOLTAGE PANEL

Masking plate and links must be positioned according to supply voltage, as shown:—

| 200-250 volts a.c. SUPPLY | LINKS | | LINKS | 100-130 volts a.c. SUPPLY |
|---|---|---|---|---|
| 200 V |  | To change voltage range, remove all links and reverse masking plate | | 100 V |
| 210 V |  | | | 105 V |
| 220 V | | |  | 110 V |
| 230 V | | |  | 115 V |
| 240 V |  | | | 120 V |
| 250 V |  | | | 130 V |

## SUPPLY VOLTAGE PLUG SETTINGS

## 4.4 REPLACEMENT OF VALVES AND CRYSTALS

All l.f. and power unit valves are immediately accessible on removing the instrument case as described in Section 4.5.1. The two remaining valves, V8 and V9, are enclosed within the r.f. unit; to remove the r.f. unit cover, refer to Section 4.5.3. The method of removing V9 (a disk-seal triode) is given in Section 4.5.4.

For details of suitable replacement valves, refer to the Valve Replacement Data Sheets, VRD 1066B, supplied with this handbook.

When replacing V8, check the deviation calibration accuracy as detailed in Section 4.9.7. When replacing V10, check the modulation monitor accuracy as detailed in Section 4.9.11.

The r.f. level detector diode (silicon-crystal), MR6, is mounted adjacent to the mouth of the piston attenuator tube; to remove this diode, refer to Section 4.5.5. The modulation monitor diodes, MR4 and MR5, are mounted on the l.f. chassis adjacent to the modulation transformer, T1.

If MR6, MR4 and/or MR5 are replaced, check the carrier-level and modulation monitor accuracies as detailed in Section 4.9.5. and 4.9.11.

## 4.5 DISMANTLING THE INSTRUMENT

### 4.5.1 To Remove the Case

(1) Lay the instrument on its face.

(2) Take out the four countersunk screws holding the case feet to the instrument.

(3) Take out the four similar screws from the rear of the case.

(4) Lift the case upwards, allowing the mains lead to pass freely through the aperture in the left-hand case-handle recess.

### 4.5.2 To Remove the Front Panel Surround

(1) Remove the instrument case as described in Section 4.5.1.

(2) Take out the fourteen cheese-headed screws around the rear edge of the front panel.

4.5.3 To Remove the R.F. Unit Covers

(1) Remove the instrument case as described in Section 4.5.1.

(2) The r.f.-unit covers comprise three flat plates - one on each of the top rear and bottom sides of the r.f. unit casting looking from the front of the instrument. Remove the sixteen cheese-headed screws from around the edges of each plate.

4.5.4 To Remove the Oscillator Valve, V9

(1) Remove all three r.f.-unit covers as described in Section 4.5.3.

(2) Slacken the screws holding the corrugated bands round the anode and grid rings of the valve.

(3) Pull the valve out through the bottom of the instrument, at the same time releasing the cathode and heater sockets which are a push fit.

4.5.5 To Remove the R.F. Level Monitor Diode, MR6

(1) Remove the bottom r.f.-unit cover as described in Section 4.5.3.

(2) Pull the diode clear of its retaining spring with the aid of a pair of small forceps. The diode can then be removed completely from the attenuator assembly.

4.5.6 To Remove the Frequency Dial and Dial Housing

(1) Detach the perspex dial cover, its centre mask, and the spring beneath the mask, by releasing the captive screw at the centre of the dial. Lift out the cursor.

(2) Remove the dial after taking out the three countersunk screws from around the centre of the dial.

(3) Remove the dial housing by undoing four nuts exposed by the removal of the dial.

4.5.7 To Remove the F.M. Deviation Tracking Potentiometer, RV21

(1) Remove the instrument case as described in Section 4.5.1.

(2) Remove the frequency dial and dial housing as described in Section 4.5.6.

(3) Slacken the two grub-screws securing the potentiometer spindle to its associated gearwheel.

(4) Undo the nut which holds the potentiometer to its spring-tensioned support bar.

(5) Withdraw the potentiometer. The gearwheel can now also be removed.

It is important that the angular position of RV21 is correctly set relative to the rotor of the tuning capacitor. The setting must be such that the rotation of the frequency control is limited by the stop mechanism in the 55:1 reduction unit and not by the end stops of the potentiometer.

Therefore, when reassembling the gear drive assembly, make sure that the gears are meshed in their correct relative positions and check the f.m. deviation accuracy as described in the appropriate sub-section of Section 4.9, SCHEDULE OF TESTS. Also check the accuracy of frequency calibration; the position of the frequency dial gear will most probably have been altered.

The method of adjusting the positions of the gears is detailed in Section 4.5.10.

4.5.8 To Remove the R.F. Unit

It is strongly recommended that the component parts of the r.f. unit should not be dismantled or their positions altered unless it is absolutely necessary and unless the user has the necessary test equipment at his disposal for recalibration. Where practicable, the Signal Generator should be returned to Marconi Instruments Service Department for repair and recalibration.

If the drive gears are unmeshed for any reason, refer to the final paragraphs of Section 4.5.10.

4.5.8 (continued)

(1) Remove the instrument case as described in Section 4.5.1.

(2) Remove the frequency dial and the dial housing as described in Section 4.5.6.

(3) Remove the r.f. unit covers as described in Section 4.5.3.

(4) Detach the COARSE FREQUENCY and RANGE Mc/s control knobs by removing the screw from the centre of each.

(5) Unsolder the four leads which connect the r.f. unit with the main body of the instrument.

(6) Slacken the two grub-screws which secure the bellows coupling to the piston attenuator pinion spindle.

(7) Remove the R.F. OUTPUT socket from the front panel.

(8) Take out eight screws from the front panel and remove the r.f. unit and attenuator assembly complete from the instrument.

4.5.9 To Remove the Filter Unit Assemblies

(1) Remove the instrument case as described in Section 4.5.1.

(2) Remove the rear r.f.-unit cover as described in Section 4.5.3.

(3) Unsolder the leads from the terminals of the appropriate filter or filters.

(4) Extract the four screws holding the appriopriate filter unit to the side of the r.f. box.

(5) Withdraw the filter unit from the r.f.-unit assembly. The four filters mounted along the rear edge of the r.f. box are withdrawn from the inside whereas the other filter (in V9 h.t. line) nearest the front panel is withdrawn outwards.

4.5.9 (continued)

It is not advisable to separate the inner and outer sections of the filter units unless the user has suitable equipment available. This is because the two sections are a tight fit and soldered to ensure good screening. If a hand press is available, the inner section can be pushed out by the application of a suitably shaped drift after the solder has been removed.

4.5.10 To Remove the Frequency Drive Gears

(a) Remove the instrument case as described in Section 4.5.1.

(1) Frequency Dial Gear

(b) Slacken the two grub-screws which hold the gearwheel to the frequency dial spindle and remove the gear.

(2) Potentiometer Gear

(c) Remove the frequency dial as described in (1) and (2) of Section 4.5.6.

(d) Slacken the two grub-screws which hold the gear to the potentiometer spindle.

(e) Unscrew the nut which secured the potentiometer to its support arm and pull the potentiometer through the cut-out in the dial housing until the spindle is clear of the gear.

(3) 55:1 Reduction Unit

(f) Remove the frequency dial housing as described in (3) of Section 4.5.6.

(g) Remove the r.f. unit as described in Section 4.5.8.

(h) Slacken the two grub-screws which hold the bellows coupling to the reduction unit 'output' spindle.

(i) Detach the four screws from the resistance panel incorporating R33 to R37 etc., on the left-hand side of the r.f. box, and move the panel to one side.

4.5.10 (continued)

(j) Remove the two cheese-headed screws thus exposed and pull the reduction unit clear of the main assembly.

(4) Bottom Gear

(k) Slacken the two grub-screws which hold the bellows coupling to the tuning capacitor rotor spindle and pull the bottom gear clear of the main assembly.

It is important that the angular positions of the frequency dial and of the f.m.-deviation-potentiometer gears are correctly set relative to the rotor of the tuning capacitor. This is necessary so that the frequency calibration remains correct and so that the limit of rotation is controlled by the stop mechanism in the 55:1 reduction unit and not by the end stops of the potentiometer.

Therefore, when reassembling the gear drive assembly, make sure that the gears are meshed in their correct relative positions and check the frequency calibration and f.m. deviation accuracy as described in the appropriate sub-section of Section 4.4, SCHEDULE OF TESTS.

To alter the position of either or both of the upper gears, it is first necessary to bring the stop bar away from the potentiometer support arm; this stop is held in position by two nuts, one on either side of the r.f. unit support casting. The gears can then be unmeshed and their positions adjusted as necessary.

When the gears are correctly meshed, the stop bar must be adjusted so that the potentiometer gear cannot come out of mesh.

4.5.11 To Remove the Attenuator Piston

(1) Remove the instrument case as described in Section 4.5.1.

(2) Detach the r.f. output socket from the front panel.

(3) Slacken the grub screws which hold the attenuator drive pinion to its shaft, and then slide the pinion off the shaft.

(4) Remove the nuts from the two long screws which secure the attenuator rack guide; now remove the guide and flat spring, and remove the guide support pillars to allow the complete piston and rack assembly to be withdrawn from the cylinder.

4.5.11 (continued)

NOTE: Great care must be taken when withdrawing the piston from the cylinder, to ensure that the beryllium copper earthing tongues around the periphery of the piston do not suffer any damage. This also applies when replacing the piston.

When the piston/rack assembly has been replaced, and the sprung rack guide re-fitted, push the piston right up the cylinder until the rack reaches its end stop. Now turn the attenuator control to maximum coupling. Finally slide the drive pinion back onto its shaft and tighten the grub screws. After assembly has been completed, the r.f. level and amplitude modulation accuracy should be checked as described in Section 4.9.

## 4.6 WORKING VOLTAGES

The following power supply and valve electrode voltages were obtained from a representative TF 1066B: the voltmeter employed had a resistance of 20 kΩ/volt.

### 4.6.1 Power Supply Voltages

| | | |
|---|---|---|
| HT a.c. | (across transformer tags X and Y on T2) | 200-0-200 V d.c. |
| HT a.c. | (pins 4 and 6 of V2 and chassis) | 350-0-350 V a.c. |
| HT rect. | (top cap of V3 and chassis) | 410 V d.c. |
| HT ref. | (Pin 2 of V5 and chassis) | 83 V d.c. |
| HT stab. | (Pin 3 of V3 and chassis)* | 280 V d.c. |
| -ve line | (chassis and pin 2 of V7) | 108 V d.c. |

* adjusted by means of RV3

| | | |
|---|---|---|
| LT1 | (across transformer tags on T2) | 6.3 V a.c. |
| LT2 | (across transformer tags on T2) | 6.3 V a.c. |
| LT3 | (across transformer tags on T2) | 5.0 V a.c. |
| LT4 | (across tags 'S' and 'F' on T2) | 21 V a.c. |
| V9 fil. | (across cathode/heater socket of V9)** | 6.3 V d.c. |

** adjusted by means of RV4

### 4.6.2 Electrode Voltages

The controls to be set as follows :-

Carrier Frequency: 20 Mc/s: Modulation Switch: INT. F.M.

4.6.2 (continued)

| | |
|---|---|
| MOD. FREQ. Switch:- | 1 kc/s |
| CARRIER LEVEL Meter:- | SET CARRIER Mark |
| Deviation:- | 100 kc/s |

| Valve | $V_a$ | $V_{sc}$ | $V_k$ |
|---|---|---|---|
| V1 | 260 | - | 9 |
| V4 | 250 | 250 | 23 |
| V8 | 220 | 220 | 17 |
| V9 | 150 | - | - |
| V10a | 92 | - | 5.5 |
| V10b | 280 | - | 75 |

| Transistor | $V_e$ | $V_c$ | $V_b$ |
|---|---|---|---|
| VT1 | - | -0.5 | +5.9 |
| VT2 | -0.3 | -4.8 | -0.5 |
| VT3 | 0 | -4.8 | -0.3 |

## 4.7 D.C. RESISTANCE OF INDUCTORS

The following approximate d.c. resistance of inductors and transformers are included to assist the user in the routine maintenance of the Signal Generator. No values are quoted where the resistance is too low to give a readable indication on a multi-range testmeter.

| Component | Approximate D.C. Resistance |
|---|---|
| L11 | 170Ω |
| L2 | 1000 Ω |
| L5 + L6 | 11 Ω |
| L3 + L4, L7 + L8 | 11 Ω |
| L20 + L21 | 11 Ω |
| T2 (Pri. 'TAP B' to '140/240V') | 15 Ω |
| T2 (Pri. 'TAP B' to '120/220V') | 13 Ω |
| T2 (Pri. 'TAP B' to '105V') | 11.5 Ω |
| T2 (Pri. 'TAP B' to '100/200V') | 11 Ω |
| T2 (Pri. 'TAP A' to 'OV') | 10 Ω |
| T2 (Pri. 'TAP A' to '+10V') | 11 Ω |
| T2 (Sec. 'HT - CT - HT') | 200-0-200 Ω |

4.7 (continued)

| Component | Approximate D.C. Resistance |
|---|---|
| T1 ('1' to '2') | 180 Ω |
| T1 ('1' to '4') | 220 Ω |
| T1 ('5' to '7') | 55 Ω |
| T3 ('Red' to 'Black') | 220 Ω |

4.8 PRESET OR SPECIALLY SELECTED COMPONENTS

In the manufacturing data for the TF 1066B, certain of the components are either specified as being of the preset type or designated for individual selection, the setting or selection of the components being carried out during the factory calibration of the instrument; this is necessary since the operating characteristics of the instrument have to conform to a quantitative specification including maximum and minimum limits of permissible error.

Components which are individually selected are distinguished on the Circuit Diagram and Component List by the identification 'S.L.C.'

If, in servicing a TF 1066B, it is necessary to replace any of these components, it is also necessary, if the performance or accuracy of the instrument is not to be impaired, to repeat the factory calibration procedure by which the components were originally selected.

Section 4.9 gives a range of tests by which the main points of performance of the instrument can be checked; this section also deals with the adjustment of preset components and with the choice of value for individually selected components.

It will be appreciated that it may sometimes be necessary to reselect a selected component, or readjust a preset component, even though that component itself has not been found faulty and replaced in initial servicing operations. For example, the potentiometer forming the correcting network preceding the reactor driver valve V9, must be adjusted to suit the characteristics of the ferrite modulator, T3. If T3 were replaced, then it would be quite likely that with the original setting the f.m. deviation would be outside the specified limits of accuracy and that preset potentiometers RV24 and RV25 would have to be readjusted.

4.8 (continued)

It therefore follows that, in all servicing operations involving replacement of components, the user should consider carefully the possible effects on the performance of the stage or stages involved.

The table which follows lists all the preset and specially selected components contained in the instrument and indicates the section in which adjustment or selection of each component is described.

| Component | Section Describing Adjustment or Selection | Component | Section Describing Adjustment or Selection |
|---|---|---|---|
| RV3 | 4.9.6 | R35 | 4.9.9 |
| RV5 | 4.9.8 (A) | R36 | 4.9.9 |
| RV6 | 4.9.8 (B) | R37 | 4.9.9 |
| RV7 | 4.9.8 (C) | R52 | 4.9.10 |
| RV8 | 4.9.8 (D) | R56 | 4.9.8. (A) |
| RV9 | 4.9.8 (E) | R66 | 4.9.11 |
| RV10 | 4.9.8 (A) | R73 | 4.9.5 |
| RV11 | 4.9.8 (B) | R74 | 4.9.5 |
| RV12 | 4.9.8 (C) | R75 | 4.9.5 |
| RV13 | 4.9.8 (D) | R76 | 4.9.5 |
| RV14 | 4.9.8 (E) | R77 | 4.9.5 |
| RV24 | 4.9.7 | | |
| RV25 | 4.9.7, 4.9.8 | | |
| RV26 | 4.9.11 | C1 | 4.9.4 |
| RV27 | 4.9.5 | C2 | 4.9.4 |
| | | C35 | 4.9.5 |
| | | C44 | 4.9.12 |
| R26 | 4.9.6 | | |
| R29 | 4.9.6 | | |
| R30 | 4.9.6 | L13 | 4.9.3, 4.9.5 |
| R31 | 4.9.6 | L14 | 4.9.3, 4.9.5 |
| R32 | 4.9.6 | L15 | 4.9.3, 4.9.5 |
| R33 | 4.9.9 | L16 | 4.9.3, 4.9.5 |
| R34 | 4.9.9 | L17 | 4.9.3, 4.9.5 |

## 4.9 SCHEDULE OF TESTS

The following information, based on abstracts from the internal Factory Test Schedule, is included to enable the user to carry out a series of tests by which the main points of performance of the instrument can be checked; it also gives details concerning the adjustment to preset components and the choice of value for individually selected components.

### 4.9.1 Apparatus Required

(a) Insulation Tester, 750-volt.

(b) Crystal Calibrator with 5- and 1-Mc/s crystal oscillators and 'difference frequency' output facilities; Marconi Type TF 723 (Series). If available, use a calibrator with a 100-kc/s oscillator in addition to the 5- and 1-Mc/s oscillators referred to above. If a 100-kc/s oscillator is not available, refer to the note at the end of Section 4.9.3.

(c) Cathode-Ray Oscilloscope.

(d) A.F. Oscillator, 30 c/s to 100 kc/s, 25 volts output; Marconi Type TF 885 (Series).
NB. Marconi Types TF 195 (Series) and TF 894 (Series) can be used for all checks in which this item is required except the test concerning the variable INC. FREQ. control (Sections 4.9.7 and 4.9.8). Marconi Type TF 1101 is suitable for all checks except that the maximum output is 20 volts.

(e) A.C. Voltmeter, 0 to 50 volts; Marconi Types TF 428 (Series), TF 958, TF 1041 (Series), TF 1100, or TF 1300.

(f) Wave Analyser; Marconi Type TF 455E.

(g) Diode Voltmeter, 0 to 100 mV, 50-ohm impedance; for details refer to figure 1 of Drg. No. XC 35452 included at the end of this manual.

(h) Receiver, 10 to 470 Mc/s, 1 μV sensitivity.

(i) Standardized Signal Generator, 50 ohms source impedance, 100 mV output, 10 to 470 Mc/s frequency range; Marconi Types TF 801B-D (Series) or TF 1066 (Series).

4.9.1. (continued)

(j) Carrier Deviation Meter, covering the carrier frequency range 10 to 470 Mc/s, deviation range 0 to 100 kc/s; Marconi Types TF 791C, TF 928 (20 Mc/s min. carrier frequency), or TF 934 (75 kc/s max. deviation).
NB. For the F.M. on C.W. check (Section 4.9.14), where deviations of less than 100 c/s have to be measured, it is essential that the deviation meter should either be modified to operate from battery supplies, or incorporate facilities allowing its local oscillator to be brought under crystal control.

(k) Diode Mixer. ) Use in conjunction with a.f.
) oscillator (item d); for details
(l) High-Resistance headphones ) see figure 2 of Drg. No. XC 35452 included at the end of this manual

(m) Distortion Factor Meter; Marconi Type TF 142F.

4.9.2 Insulation (Apparatus Reqd: Item a)

This test can be done with the instrument in or out of its case

Measure the insulation resistance between chassis and each live pin of the mains supply plug in both positions of the SUPPLY ON/OFF switch.

The insulation resistance should be not less than 40 MΩ.

4.9.3 Frequency Calibration (Apparatus Reqd: Item b)

The frequency calibration should be checked with the instrument in its case.

Before any other adjustments are made to the r.f. unit of the Signal Generator, it is important that the tuning coils are so adjusted that the full frequency cover on each band is obtainable. For this reason, the instructions for checking the frequency calibration are given before those for the remaining tests and adjustments. However, if it is found necessary to make any major adjustment in the r.f. unit, the frequency calibration should always be rechecked.

4.9.3 (continued)

Furthermore, if it is found necessary to recalibrate the frequency dial, this should always be done finally after the other tests and adjustments detailed in this schedule have been completed. A rough calibration may be marked on the dial initially as a guide for use when making adjustments to the instruments.

The procedure for ehecking the calibration is as follows:-

(1) Switch ON the mains supply and set the modulation selector to C.W.

(2) Adjust the FINE TUNING control to mid-travel, and set the INC FREQ switch to its central zero position.

(3) Connect the output of the Signal Generator to the crystal calibrator.

(4) Check the frequency calibration accuracy against the harmonics of the 5-Mc/s and 1-Mc/s oscillator of the crystal calibrator.

The frequency calibration should be accurate to within 1% of the indicated frequency.

If the frequency calibration is inaccurate by a linearly equivalent amount on all frequency bands and over the whole of each band, the tuning dial may have moved relative to the tuning capacitor spindle.

If there is an error on one band only or irregularly distributed errors, it may be possible to correct the calibration by adjustment of the cores of the tuning inductors (L17, L15 and L13) on Bands A to C or by adjustment of the length of the inductor strips (L14 and L16) on Bands D and E.

If it is not possible to correct the existing dial calibration, fit a new blank tuning dial and recalibrate. In order to eliminate any possibility of the calibration being rendered inaccurate by subsequent adjustment to the instrument, it is advisable to make all the remaining tests and adjustments described in this schedule before proceeding to recalibrate the tuning dial.

When recalibrating the dial, it may be necessary to make an approximate calibration using a receiver (Item h of Apparatus Required) before marking the accurate calibration on the dial using the crystal calibrator. This prevents the possibility of selecting the wrong harmonic of the calibrator's crystal oscillator for any given dial marking.

4.9.3 (continued)

Calibrate the dial at:

| | | |
|---|---|---|
| every | 100 kc/s* | on Band A (10-22 Mc/s) |
| every | 200 kc/s* | on Band B (22-48 Mc/s) |
| every | 1 Mc/s | on Band C (48-110 Mc/s) |
| every | 2 Mc/s | on Band D (110-240 Mc/s) |
| every | 5 Mc/s | on Band E (240-470 Mc/s) |

* If the crystal calibrator in use does not incorporate a 100-kc/s oscillator, it is permissible, though not recommended, to calibrate every 1-Mc/s point and to interpolate the intermediate frequencies.

4.9.4 Internal Modulation Oscillator (Apparatus Reqd: Items c, d, e and f

This test should be made with the instrument out of its case.

(1) Connect the Y input terminals of the oscilloscope to the EXT MOD F.M. and earth terminals of the Signal Generator.

(2) Connect the audio-frequency oscillator to the X input of the oscilloscope.

(3) Set the modulation selector of the Signal Generator to INT F.M.

(4) Use the lissajous figure method of checking the frequency of the modulating oscillator in both the 1-kc/s and 5-kc/s positions of the MOD. FREQ. switch.

The frequency should be within 5% of that indicated by the setting of the switch. If necessary adjust the frequency by selecting new values for capacitors C1 and C2.

(5) Measure the output voltage of the modulating oscillator between tags 5 and 7 of transformer T1 by means of multi-range test meter.

The output should not be less than 25 volts.

(6) Connect the wave analyser between the EXT MOD F.M. and earth terminals of the Signal Generator and measure the levels of the 2nd and 3rd harmonics in the modulation signal. In general they can be expected to be not greater than 2.5% and 2% of the fundamental level respectively.

4.9.5 Carrier Level Monitor (Apparatus reqd: Items g, h and i)

This test should be carried out with the instrument out of its case.

The CARRIER LEVEL meter accuracy can be adjusted by means of potentiometer RV27 and resistors R73 to R77. RV27 controls the overall accuracy whereas R73 to R77 are adjusted individually for each range.

Therefore, if a constant error, common to all bands, exists, correction can be effected by adjustment of RV27. If, however, the error affects only some of the bands, the appropriate resistors, R73 to R77, should be reselected.

The complete procedure for setting up the CARRIER LEVEL monitor is given below.

(1) Connect the R.F. OUTPUT socket to the 50-ohm diode voltmeter.

(2) Set the ATTENUATOR to 100 mV ACROSS EXTERNAL LOAD.

(3) Set the frequency dial to a position about one-quarter to one-third of the total travel from the low-frequency end of the band.

At this point in the factory calibration procedure, the r.f. oscillator is adjusted so that maximum output can be obtained regardless of accuracy. This adjustment consists of (i) setting the physical position of the tuning inductors, L13 to L17, relative to the attenuator pick-up loop, and (ii) setting preset capacitor C35, between oscillator cathode and earth, for optimum output on Range E.

With some oscillator valves the anode-cathode capacitance effectively between cathode and earth is sufficient to allow an adequate r.f. output to be obtained, and in fact, the presence of additional capacitance tends to reduce the output level. If on replacing an oscillator valve this is found to be so, C35 should be removed. In the factory calibration of the instrument, C35 is only fitted when the need arises.

If any of the inductors have been replaced, the particular inductor must be rotated around the axis of its clamping screws until maximum output is observed on the external diode voltmeter before the clamping screws are finally tightened. Apart from a replacement inductor, it will only be necessary to reset the positions of the inductors if insufficient output can be obtained as indicated on the external voltmeter.

4.9.5 (continued)

To check this, switch to each band in turn and make sure that at least 100 mV can be obtained. If difficulty is experienced in obtaining the required output on the highest-frequency range (Range E), adjust capacitor C35 for optimum output over the whole range.

(4) Set the RANGE switch to 110- 240 Mc/s (Range D) and adjust the SET CARRIER control so that the voltmeter indicates exactly 100 mV.

(5) Adjust RV27 so that the CARRIER LEVEL meter reads at its SET CARRIER mark.

With operation (5), above, completed, RV27 should be at about mid-travel position. If it is found that the potentiometer is at or near the limit of its travel select a new value for R76.

(6) Switch to each band in turn and, if necessary, select a value for the appropriate series resistor so that the CARRIER LEVEL meter reads correctly when 100 mV is indicated on the external meter.

| On Band: | Adjust Resistor: | On Band: | Adjust Resistor: |
|---|---|---|---|
| A | R73 | D | R76 |
| B | R74 | E | R77 |
| C | R75 | | |

The following check must be made with the instrument in its case.

(7) Check the r.f. output level accuracy by a normal substitution method utilizing a receiver and a standardized signal generator.

The actual r.f. output level should be accurate to within 2 dB of the nominal at any frequency and at any level.

Make sure that the signal strength- as indicated by the signal-strength meter of the receiver - decreases progressively right down to 1 μV with no tendency , due to stray radiation, to increase again as the ATTENUATOR reading approaches 1 μV.

4.9.6 Coverage of SET CARRIER Control

This test should be carried out with the instrument out of its case.

Before making any adjustment to the SET CARRIER circuits, adjust the h.t. voltage level as described below.

(1) Short-circuit the EXT F.M. and earth terminals; set the INC FREQ switch to VAR; set the modulation monitor selector to INC FREQ 20 kc/s.

(2) Adjust RV3 so that the MODULATION AND INCREMENTAL FREQUENCY meter reads at its central zero mark.

When the r.f. level has been correctly set as described in Section 4.9.5, check and, if necessary, adjust the coverage of the SET CARRIER control. This is done by adjusting resistors R26 and R 29 to R32 so that the setting of the SET CARRIER potentiometer required to bring the CARRIER LEVEL meter to its reference mark is approximately the same on all bands. The method is described below.

(3) Temporarily short-circuit R24.

(4) Set the RANGE switch to Band A (10 - 22 Mc/s).

(5) Set the frequency dial to a position about one-quarter to one-third of the total travel from the low-frequency end of the band.

(6) Adjust the CARRIER LEVEL meter to the SET CARRIER mark by means of the SET CARRIER control,

(7) Switch to the remaining bands in turn and, without altering the position of the SET CARRIER control, note on which band the SET CARRIER meter indication is least.

(8) Disconnect the temporary short-circuit link across R24 and, with the RANGE switch set to the band which gives the least CARRIER LEVEL indication, short-circuit the resistor appropriate to that range.

| Min. Indiciation On Band: | Short-Circuit Resistor: |
|---|---|
| A (10 - 22 Mc/s) | R32 |
| B (22 - 48 Mc/s) | R31 |
| C (48 - 110 Mc/s) | R30 |
| D (110 - 240 Mc/s) | R29 |
| E (240 - 470 Mc/s) | R26 |

4.9.6 (continued)

(9) Switch to the remaining bands in turn and, if necessary, select values for the series resistors R26 and R29 to R31, such that the setting of the SET CARRIER control remains sensibly constant.

(10) Check that, at all carrier frequencies, the CARRIER LEVEL meter can be set to its reference mark.

4.9.7 Deviation and INC FREQ - VAR Accuracy

(Apparatus Reqd: Items b, d, j, k and l)

During the factory calibration procedure, two resistors are selected on each band in order to obtain the required deviation and variable incremental-frequency accuracy. Subsequent correction of any inaccuracy which is common to all bands can normally be effected by adjustment of preset resistors RV24 and RV25. RV24 affects both deviation and incremental frequency accuracy; RV25 affects deviation accuracy only. If, however, the error is confined to one band only, e.g., due to a faulty resistor, the procedure detailed in Section 4.9.8 should be carried out.

The procedure for adjusting RV24 and RV25 is given below.

(1) Set the RANGE switch to Band A.

(2) Connect the R.F. OUTPUT socket to the Crystal Calibrator.

(3) Connect the 'Difference Frequency' output socket on the Crystal Calibrator to some suitable means of monitoring frequencies of up to 100 kc/s; e.g., diode mixer in conjunction with an a.f. oscillator and head telephones.

(4) Set the Signal Generator modulation selector to F.M.; turn the SET MOD control to minimum, the monitor selector to INC FREQ 100 kc/s, and the INC FREQ switch to VAR.

(5) Adjust the variable INC FREQ control to give zero reading on the MODULATION AND INCREMENTAL FREQUENCY meter and adjust the COARSE and FINE TUNING controls for zero beat at 15 Mc/s against the Crystal Calibrator 5-Mc/s crystal. Turn the SET MOD control to maximum then progressively back to minimum in order to neutralize any modulator hysteresis. If necessary readjust the TUNING controls.

4.9.7 (continued)

(6) Adjust the variable INC FREQ control to give a 'Difference Frequency' output of 100 kc/s.

If necessary, adjust RV24 to produce a minimum error at both + 100 kc/s and -100 kc/s frequency shift at carrier frequencies of 15 and 22 Mc/s.

(7) Disconnect the Crystal Calibrator and, in its place, connect the R.F. OUTPUT socket to the Carrier Deviation Meter.

(8) Set the monitor selector to MOD 0-100.

(9) Check the deviation accuracy at the extremes of the carrier frequency band.

(10) Repeat (9) above on the MOD 0-20 deviation range.

If necessary, adjust RV25 to produce deviation readings with minimum error at the extremes of the carrier frequency band. Do not alter the setting of RV24.

As the potentiometer networks preceding the modulator driver, V8, are common to both deviation and frequency shift circuits, once the deviation and incremental frequency accuracies have been adjusted on Band A it is not necessary to readjust RV25 on any of the higher-frequency bands.

(11) Repeat operations (7)to(10) above on carrier-frequency Bands B, C, D, and E.

If necessary, readjust RV24 to produce deviation readings with the lowest possible maximum error, by distributing the error over the whole of the carrier-frequency range of 10 to 470 Mc/s.

The deviation direct-reading accuracy should be within ±7% of f.s.d. up to 110 Mc/s, 10% of f.s.d. up to 240 Mc/s, and 20% of f.s.d. up to 470 Mc/s.

To check the validity of the CORRECTION CHART FOR DEVIATION AND INCREMENTAL FREQUENCY MONITOR, measure the deviation at a selection of frequencies throughout the range 110 Mc/s to 470 Mc/s; the measured value and the chart reading should agree to within ±7% at all carrier frequencies. If they do not, recalibrate the chart; to order blank replacement charts, quote Drawing No. TC 25688.

4.9.8 Selection of Deviation Correcting-Network Resistors

(Apparatus Reqd: Items b, d, i, f, j, k and l)

The tests to be described in this section should only be performed if the requirements of Section 4.9.7 cannot be met.

This test should be done with the instrument out of its case.

The correcting-network potentiometers for the f.m. deviation and monitoring circuits must be adjusted in the correct sequence, because (a) the same meter is used for three separate functions - viz: monitoring of a.m. depth, f.m. deviation, and incremental-frequency shift - (b) the ferrite modulator (TR3) is used for both frequency modulation and incremental-frequency shift, and (c) the resistance of the correcting network presented to the INC FREQ circuit must remain sensibly constant for optimum working.

Before commencing any adjustments to the correcting network, check that the MODULATION AND INCREMENTAL FREQUENCY meter reads at its central zero mark when the EXT MOD F.M. and earth terminals are shorted and the monitor selector switch is set to INC FREQ 20 kc/s. If the zeroing is in error, refer to Section 4.9.6.

(A) Adjustments on Band A (10 - 22 Mc/s)

Deviation Accuracy

(1) Set the RANGE switch to Band A.

(2) Connect the R.F. OUTPUT socket to the carrier deviation meter.

(3) Set the modulation selector to INT F.M., the MOD FREQ switch to 1 kc/s, and the mod. monitor selector to MOD 0-100.

(4) Adjust the SET MODULATION control to give a deviation of approximately 100 kc/s as indicated on the carrier deviation meter.

(5) By successive adjustment of potentiometers RV10 and RV5, obtain a correct reading for carrier deviation over the carrier range 10 to 22 Mc/s.

4.9.8 (continued)

RV10 affects the 22-Mc/s end of the band more than the 10 Mc/s end, and RV5 affects the whole of the band more or less equally. The deviation accuracy should be within ±7% of f.s.d. over the whole band.

Incremental Frequency Accuracy

(6) Disconnect the carrier deviation meter and connect the R.F. OUTPUT socket to the crystal calibrator.

(7) Connect the 'Difference Frequency' output socket on the Crystal Calibrator to some suitable means of monitoring frequencies of up to 100 kc/s; e.g., diode mixer in conjunction with a.f. oscillator and headphones.

(8) Set the Signal Generator modulation selector to C.W., the monitor selector to INC FREQ 100 kc/s, and the INC FREQ switch to VAR.

(9) Adjust the variable INC FREQ control to give zero reading on the MODULATION AND INCREMENTAL FREQUENCY meter and tune the frequency controls for zero beat at 15 Mc/s against the Crystal Calibrator 5-Mc/s crystal.

(10) Adjust the variable INC FREQ control to give a 'Difference Frequency' output of 100 kc/s.

If necessary, adjust potentiometer RV5 to produce minimum error at both + 100 kc/s and - 100 kc/s frequency shift at carrier frequencies of 15 and 22 Mc/s.

General Accuracy

(11) Reconnect the R.F. OUTPUT socket to the Carrier Deviation Meter.

(12) Set the monitor selector to MOD 0-100.

(13) Check the deviation accuracy at the extremes of the carrier frequency band.

If necessary, adjust RV25 to produce deviation readings with negligible error at the extremes of the carrier frequency band. Do not alter the settings of RV10 and RV5.

4.9.8 (continued)

(14) Set the monitor-selector switch to MOD 1-20.

(15) Check the deviation accuracy at the extremes of the carrier frequency band.

If necessary, select a value for R56 to produce deviation readings with negligible error at the extremes of the carrier frequency band. Do not alter the settings of RV10 and RV5.

The deviation accuracy should be within ±7% of f.s.d., and the incremental-frequency accuracy within ±1.7% of f.s.d., at all carrier frequencies within the range 10 to 22 Mc/s.

(B) Adjustments on Band B (22 - 48 Mc/s)

(16) Set the RANGE switch to Band B.

(17) Carry out a procedure similar to that described in (3) to (5) under part (A) of this section; the potentiometers concerned are RV11 and RV6.

RV11 affects the 48-Mc/s end of the band more than the 22-Mc/s end, and RV6 affects the whole of the band more or less equally. The deviation accuracy should be within ±7% of f.s.d. over the whole of the band.

(C) Adjustments on Band C (48 - 110 Mc/s)

(18) Set the RANGE switch to Band C.

(19) Carry out a procedure similar to that described in (3) to (5) under part (A) of this section; the potentiometers concerned are RV7 and RV12.

RV12 affects the 110 Mc/s end of the band more than the 48-Mc/s end, and RV7 affects the whole of the band more or less equally. The deviation accuracy should be within ±7% of f.s.d. over the whole of the band.

(D) Adjustments on Band D (110 - 240 Mc/s)

(20) Set the RANGE switch to Band D.

4.9.8 (continued)

(21) Carry out a procedure similar to that described in (3) to (6) under part (A) of this section; the potentiometers concerned are RV8 and RV13.

RV13 affects the 240-Mc/s end of the band more than the 110-Mc/s end, and RV8 affects the whole of the band more or less equally.

(22) Check the deviation accuracy at a selection of frequencies throughout the band and insert the correction figures obtained on the CORRECTION CHART FOR DEVIATION AND INCREMENTAL FREQUENCY MONITOR. To order blank replacement charts, quote Drawing No. TC 25688. The direct-reading accuracy should be generally within ±7% at all carrier frequencies.

(E) Adjustments on Band E (240 - 470 Mc/s)

(23) Set the RANGE switch to Band E.

(24) Carry out a procedure similar to that described in (3) to (6) under part (A) of this section; the potentiometers concerned are RV9 and RV14.

RV14 affects the 470-Mc/s end of the band more than the 240-Mc/s end, and RV9 affects the whole of the band more or less equally.

(25) Check the deviation accuracy at a selection of frequencies throughout the band and insert the correction figures obtained on to the CORRECTION CHART FOR DEVIATION AND INCREMENTAL FREQUENCY MONITOR. To order blank replacement charts, quote Drawing No. TC 25688. The direct-reading accuracy should be within ±20% at all carrier frequencies.

4.9.9 Switched INC FREQ Steps

(A) So that the shift is as near constant as possible over the whole of the carrier frequency band, the impedance presented to the incremental frequency circuit RV15 to RV20 etc., by the f.m. input divider, must remain substantially level at all carrier frequencies. This is achieved as described below.

4.9.9 (continued)

This part need only be carried out if the deviation correcting-network resistors have been altered as in Section 4.9.8, or if it is considered otherwise necessary to check and correct the impedance referred to above.

This test should be done with the instrument out of its case.

(1) Set the frequency dial to a position about one-quarter to one-third of the total travel from the low-frequency end of the band.

(2) Set up the Signal Generator for 60-kc/s internal f.m. at a modulation frequency of 1 kc/s.

(3) Switch to each carrier frequency band in turn and, with resistors R33 to R37 open-circuited, without altering the position of the SET MODULATION control, note on which band the modulation monitor indication is least.

(4) On this band adjust the SET MODULATION control so that the meter reads at 60 kc/s deviation.

(5) On the remaining bands select values of f.m. potentiometer shunt resistors, R33 to R37, so that the meter reads at 60 kc/s for the setting of the SET MODULATION control obtained in (4) above.

| On Band: | Adjust Resistor: |
|---|---|
| A (10-22 Mc/s) | R37 |
| B (22-48 Mc/s) | R36 |
| C (48-110 Mc/s) | R35 |
| D (110-240 Mc/s) | R34 |
| E (240-470 Mc/s) | R33 |

(B) The desired values of shift for the switched INC FREQ steps are set up as described below.

This test can be made with the instrument in its case.

(1) Set the INC FREQ control to VAR, and the monitor selector switch to INC FREQ 100 kc/s.

4.9.9 (continued)

(2) Neutralize any modulator hysteresis by 'wiping' the variable control to maximum shown on the meter, and then back again to zero.

(3) Set the INC FREQ switch to the position required to be set up, and select the sensitivity of the monitor meter for the most suitable range.

(4) Now adjust the appropriate pre-set potentiometer until the increment required is indicated on the meter.

The potentiometers are marked '+1', '-1' etc, to correspond with the INC FREQ switch positions, and are mounted on a panel which is behind the hinged flap in the rear of the case. The free edge of the flap is secured by a single screw.

4.9.10 External F.M. Characteristic (Apparatus Reqd: Items d and j)

This test can be done with the instrument in or out of its case.

Check the frequency characteristic of the EXT F.M. input circuit in the following manner:

(1) Connect the R.F. OUTPUT socket to the carrier deviation meter.

(2) Set the RANGE switch to Band A and the frequency controls to 16 Mc/s.

(3) Set the modulation selector to EXT F.M. and the modulation monitor selector to MOD 0 - 100.

(4) Connect the a.f. oscillator to the EXT F.M. and earth terminals; set its frequency to 1000 c/s and adjust its output to produce a carrier deviation of 60 kc/s.

(5) Keep the a.f. input voltage constant and check the Signal Generator meter reading against the Carrier Deviation Meter indication over the modulating frequency range 30 c/s to 15 kc/s.

The a.f. input voltage required to produce 100 kc/s deviation should not exceed 25 volts at 1000 c/s. The variation in required input level should not exceed 10% relative to the reading at 1000 c/s,

4.9.10 (continued)

and the error in the Signal Generator deviation indication should not exceed 5% of full scale deflection at all modulation frequencies.

If the frequency characteristic is in error, correction can be effected by adjustment of R52, the resistor connected across the ferrite modulator, T3.

4.9.11 A.M. Calibration Accuracy (Apparatus Reqd: Items c and h)

This test should be done with the instrument in its case.

Check the accuracy of the amplitude-modulation indicator in the following manner:

(1) Connect the R.F. OUTPUT socket to the input of the receiver.

(2) Connect the 'I.F. Output' of the Receiver to the 'Y Input' of the Oscilloscope.

(3) Set the RANGE switch to Band A, the frequency controls to 10 Mc/s, and the modulation selector to C.W.

(4) Adjust the receiver tuning to give maximum deflection of the c.r.o. beam and, by means of the ATTENUATOR control, adjust the r.f. level to produce a display of convenient amplitude.

(5) Set the modulation selector to INT A.M. and the monitor selector to MOD 0-100.

(6) Adjust the SET MODULATION control to give 40% modulation depth as measured on the oscilloscope screen by the use of the formula

$$M\,(\%) = \frac{D_{max} - D_{min}}{D_{max} + D_{min}} \times 100$$

where $D_{max}$ is the peak-to-peak dimension of the c.r.o. display and $D_{min}$ is the trough-to-trough dimension of the c.r.o. display. If necessary, adjust RV26 to bring the meter indication to exactly 40%.

4.9.11 (continued)

If it is found that the required setting for RV26 is at or near the limit of its travel, set RV26 to mid-position and adjust R66 to bring the meter indication to about 40%; finally, adjust the meter reading by means of RV26.

(7) Check the scale shape of the monitor meter on both its 0-100 and 0-20 scales up to 40% modulation; the maximum permitted error is 5% modulation on the 0-100 scale and 2% modulation on the 0-20 scale. If necessary, readjust RV26 to a position where the calibration is within the above tolerances at all modulation depths.

4.9.12 External A.M. Characteristic (Apparatus Reqd: Items c, d and h)

This test can be done with the instrument out of its case.

Check the frequency characteristic of the EXT A.M. input circuit in the following manner:

(1) Connect the R.F. OUTPUT socket to the input of the Receiver.

(2) Connect the 'I.F. Output' of the Receiver to the 'Y Input' of the Oscilloscope.

(3) Set the RANGE switch to Band A and the frequency control to 16 Mc/s.

(4) Set the modulation selector to EXT A.M. and the modulation monitor to MOD 0-100.

(5) Connect the a.f. oscillator to the EXT MOD A.M. and earth terminals; set its frequency to 1000 c/s and adjust its output level to produce a modulation depth of 40%.

(6) Tune the Receiver for maximum display amplitude on the Oscilloscope.

(7) Keep the a.f. input voltage constant and check the Signal Generator meter reading against the oscilloscope indication over the modulating frequency range 30 c/s to 15 kc/s.

4.9.12 (continued)

The a.f. input voltage required to produce 30% modulation should not exceed 10 volts at 1000 c/s. The variation in required input level should not exceed 1 dB relative to the reading at 1000 c/s, and the error in the Signal Generator modulation depth indication should not exceed 5% modulation at any modulation frequency.

If the frequency characteristic is in error, correction can be effected by adjustment of C44 in the cathode circuit of the a.f. amplifier, V10.

4.9.13 Hysteresis of the Ferrite Modulator (Apparatus Reqd: Item b)

This test should be done with the instrument in its case.

Check the degree to which the hysteresis effect of the ferrite modulator affects the INC FREQ accuracy in the following manner:

(1) Connect the R.F. OUTPUT socket to the Crystal Calibrator.

(2) Set the RANGE switch to Band A and the frequency controls to 15 Mc/s.

(3) Set the modulation selector to INT F.M. and the monitor selector to INC FREQ 100 kc/s.

(4) With the SET MODULATION control fully counter-clockwise and the INC FREQ kc/s switch at VAR, adjust the INC FREQ control to bring the meter reading to its central zero position.

(5) Turn the SET MODULATION control fully clockwise and then slowly back to zero in order to neutralize the hysteresis of the ferrite modulator. If necessary, readjust the INC FREQ meter zero.

(6) Tune the Signal Generator for zero beat against the 5-Mc/s crystal of the Crystal Calibrator.

(7) Turn the INC FREQ control to produce 100 kc/s shift and then back to the zero-beat position.

4.9.13 (continued)

The change in meter indication after this operation is due to hysteresis and should not exceed 5 kc/s. If the change is greater than 5 kc/s, then a faulty ferrite modulator, T3, is indicated. The amounts by which the change exceeds 5 kc/s and the accuracy required by the user will determine whether or not this component need by changed.

4.9.14 Spurious F.M. on C.W. (Apparatus Reqd: Items j and m)

This test should be done with the instrument in its case.

Any spurious f.m. content of a c.w. output signal is due mainly to hum at the r.f. oscillator valve; the spurious f.m. should be less than 100 c/s deviation at all carrier frequencies. To check this, the test detailed in the following paragraphs should be carried out.

(1) Connect the R.F. OUTPUT socket to the Carrier Deviation Meter.

Note that since the deviation to be measured is as low as 100 c/s it is essential that the Deviation Meter itself generates negligible spurious f.m. This can be achieved either by modifying the deviation meter to operate from batteries or by using a deviation meter whose local oscillator can be brought under crystal control.

(2) In order to detect the small amount of deviation accurately, connect the Distortion Factor Meter to the 'L.F. Output' terminals of the Carrier Deviation Meter. A simple low-pass filter (to prevent the passage of the i.f. from the Deviation Meter) should be inserted between the two instruments; a three-stage R/C filter, using 470-ohm resistors and 0.01-μF capacitors, is normally employed.

Instead of a Distortion Factor Meter, a step-attenuator and a sensitive valve voltmeter (e.g, Marconi Types TF 1100, TF 1371, and TF 1375) may be used.

(3) Set up the Signal Generator for a carrier frequency of, say, 10 Mc/s, and frequency-modulate this to exactly 10 kc/s deviation.

(4) Tune the Deviation Meter to 10 Mc/s.

4. 9.14 (continued)

(5) Set the Distortion Factor Meter coarse input attenuator to maximum attenuation, and set its main selector switch to READ DISTORTION x 1.

(6) Adjust the DISTORTION PERCENT control, and if necessary, the attenuator controls, so that the meter pointer reads to the black line on the dial.

(7) Now remove the frequency modulation from the r.f. carrier, and turn the Distortion Factor Meter input attenuator down by 40 dB. The deflection now on the meter should be below the black line, i.e. a deviation of less than 100 c/s.

(8) Repeat operations (3) to (7) for a selection of carrier frequencies up to 470 Mc/s; the deviation should remain at less than 100 c/s.

If the spurious f.m. is greater than 100 c/s, and if a low value of spurious f.m. is of prime importance, then it will be necessary to replace V8 or, more occasionally, V9. It is recommended that, before replacing either of these valves, the power supply d.c. voltages should be checked for hum.

The second form of spurious f.m. is due to microphony. During the factory calibration procedure, the microphony is checked by means of a 50-c/s transducer unit which is bolted to the Signal Generator frame.

It is difficult to specify a standard transducer for this purpose, but a good substitute is to connect the Signal Generator to the Carrier Deviation Meter, and then to give the Signal Generator front panel a sharp, hard rap with the knuckle. The transient deviation caused by this action should not exceed about 10 kc/s.

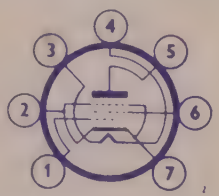
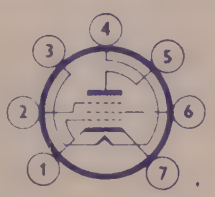
# Valve Replacement Data

**for**

**F.M. SIGNAL GENERATOR TYPE TF 1066B**

Any valve which becomes faulty should preferably be replaced by a valve of the type originally supplied in the instrument and designated in the following table. If this is not possible, the additional data given by the table may be used as a guide to suitable alternatives.

| *Valve* | *British Commercial Equivalent* | *British Services Equivalent* | *Base* | *U.S. Equivalent* |
|---|---|---|---|---|
| V1<br>TRIODE<br>BRIMAR<br>6C4 | EC90 | CV133<br>L77 | MINIATURE 7-PIN (B7G)<br> | 6C4 |
| V2<br>FULL-WAVE RECTIFIER<br>BRIMAR<br>5Z4G | | CV1863 | INTERNATIONAL OCTAL<br> | 5Z4G |
| V3<br>TETRODE<br>BRIMAR<br>6CD6G | | | INTERNATIONAL OCTAL<br> | 6CD6G |
| V4<br>TETRODE<br>MULLARD<br>6L6G | KT66 | CV1947 | INTERNATIONAL OCTAL<br> | 6L6G |

| *Valve* | *British Commercial Equivalent* | *British Services Equivalent* | *Base* | *U.S. Equivalent* |
|---|---|---|---|---|
| V5<br>PENTODE<br>BRIMAR<br>6AK5 | EF95 | CV850 | MINIATURE 7-PIN (B7G)<br>  | 6AK5 |
| V6<br>VOLTAGE STABILIZER<br>MULLARD<br>5651 | QS1209<br>QS83/3 | CV449<br>CV2573 | MINIATURE 7-PIN (B7G)<br> | 5651 |
| V7<br>VOLTAGE STABILIZER<br>BRIMAR<br>0B2 | 108C1<br>QS1208 | CV1833 | MINIATURE 7-PIN (B7G)<br> | 0B2 |
| V8<br>POWER PENTODE<br>BRIMAR<br>6AK6 | | CV1762 | MINIATURE 7-PIN (B7G)<br>  | 6AK6 |
| V9<br>DISC SEAL TRIODE<br>MULLARD<br>TDO3 10 | | CV273 | SPECIAL<br> | 5861 |

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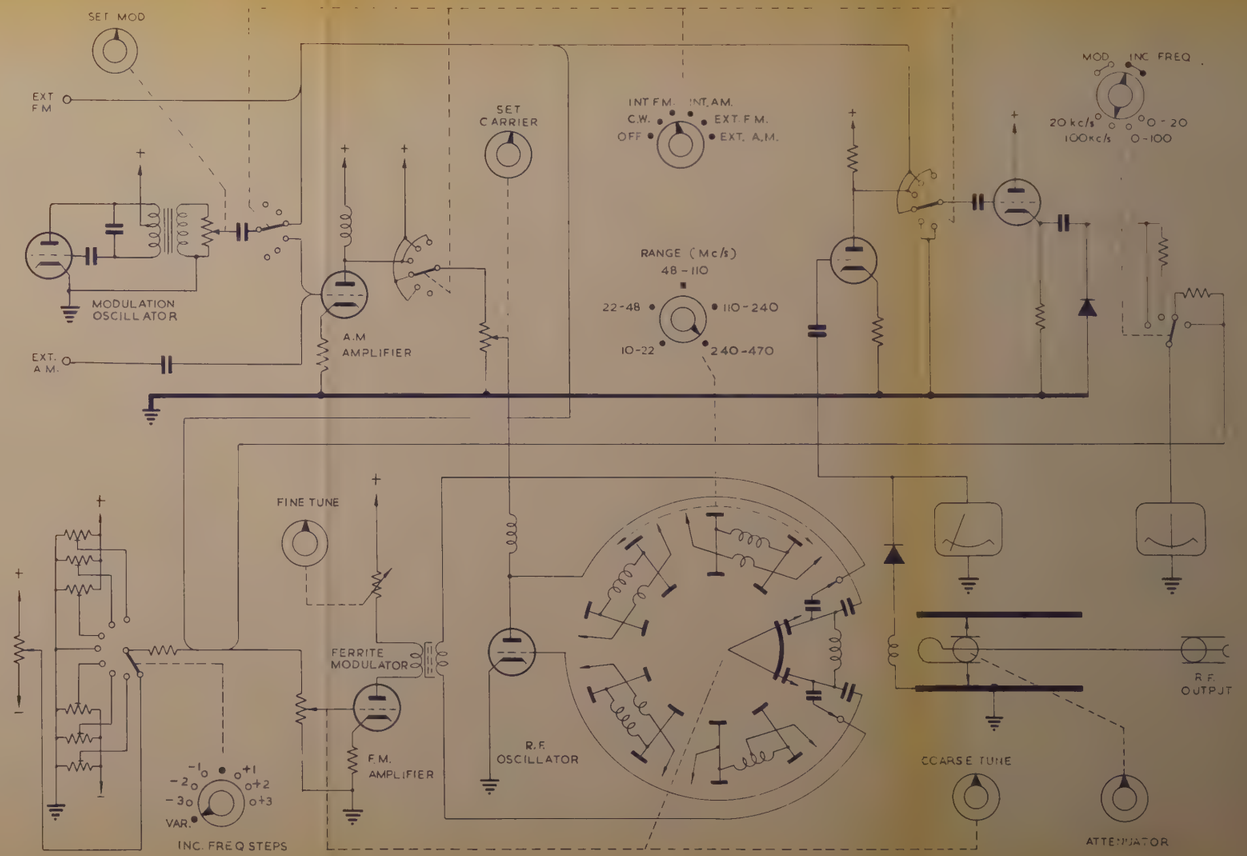
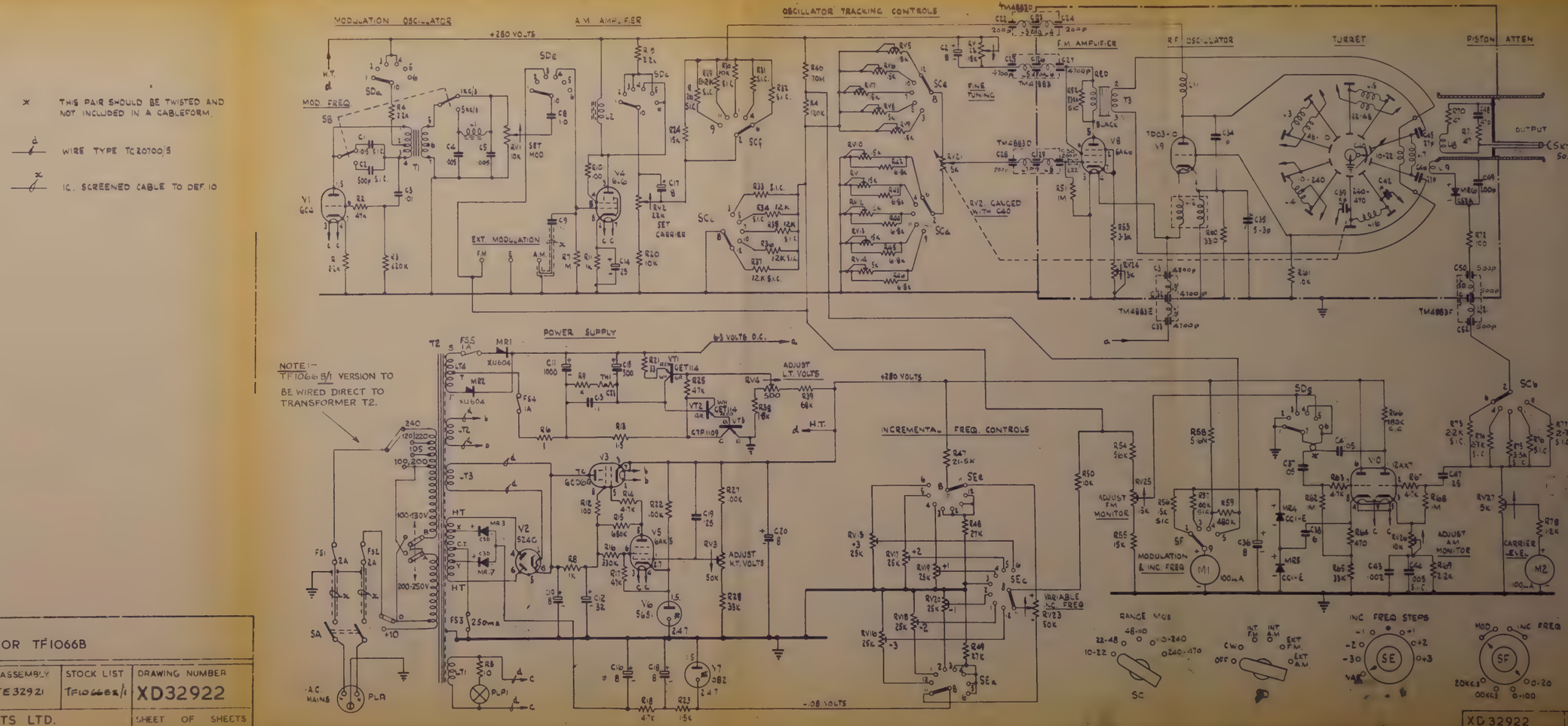
| *Valve* | *British Commercial Equivalent* | *British Services Equivalent* | *Base* | *U.S. Equivalent* |
|---|---|---|---|---|
| **V10** | | | MINIATURE 9-PIN (B9A) | |
| DOUBLE TRIODE<br>BRIMAR 12AX7 | ECC83<br>B339 | CV492 | | 12AX7 |




FUNCTIONAL DIAGRAM OF F.M. SIGNAL GENERATOR TYPE TF1066B

| TITLE | | | | | | | |
|---|---|---|---|---|---|---|---|
| FUNCTIONAL DIAGRAM OF F.M. SIGNAL GENERATOR TYPE TF1066B | | | | | | | |
| DRAWN | DATE | CHKD. | APPD. | TRC'D. | ASSEMBLY | STOCK LIST | DRAWING NUMBER |
| M.C | 12/60 | TRJ | | H.F. | | TF 1066 B | XD 35453 |
| MARCONI INSTRUMENTS LTD. | | | | | | | SHEET 1 OF 1 SHEETS |

23 AUG 1966
MARC
INST. L




× THIS PAIR SHOULD BE TWISTED AND NOT INCLUDED IN A CABLEFORM.

WIRE TYPE TC20700/5

IC. SCREENED CABLE TO DEF. 10

TITLE

F.M. SIGNAL GENERATOR TF1066B

| DRAWN | DATE | CHKD | APPD | TRCD | ASSEMBLY | STOCK LIST | DRAWING NUMBER |
|---|---|---|---|---|---|---|---|
| P.H. BAKER | 6/60 | | | E.M.T. | TE32921 | TF1066B/1 | XD32922 |

MARCONI INSTRUMENTS LTD. SHEET OF SHEETS

XD32922

ISSUE NO. 5

| CIR REF | DESCRIPTION | GRID | STOCK LIST REF. | CIR. REF. | DESCRIPTION | GRID | STOCK LIST REF. |
|---|---|---|---|---|---|---|---|
| | [illegible] | | | R27 | [illegible] | C5 | [illegible] |
| R1 | [illegible] | D1 | 28. TM6271 | R28 | [illegible] | C5 | [illegible] |
| R2 | [illegible] | D2 | 41. TM6271 | R29 | 8·2KΩ ± 10% 1W | C1 | [illegible] |
| R3 | [illegible] | D3 | 30. TM6271 | R30 | 10 KΩ ± 10% 1W | C1 | [illegible] |
| R4 | [illegible] | D1 | 28. TM6271 | R31 | S.I.C. | B1 | 4. [illegible] |
| R5 | [illegible] | E5 | 31. TM6271 | R32 | S.I.C. | C4 | [illegible] |
| R6 | [illegible] | E4 | 32. TM6271 | R33 | S.I.C. | C2 | [illegible] |
| R7 | [illegible] | E3 | 33. TM6271 | R34 | 12 KΩ S.I.C. [illegible] | C | 5. [illegible] |
| R8 | 1KΩ ± 10% [illegible] | E5 | 34. TM6271 | R35 | 12 KΩ S.I.C. [illegible] | C2 | 5. [illegible] |
| R9 | 1KΩ ± 10% [illegible] | E4 | 34. TM6271 | R36 | 12 KΩ S.I.C. [illegible] | C3 | 5. [illegible] |
| R10 | 100Ω ± 10% [illegible] | E2 | 35. TM6271 | R37 | 12 KΩ S.I.C. [illegible] | C3 | 5. [illegible] |
| R11 | [illegible] | E3 | 36. [illegible] | R38 | 1·8K ± 10% [illegible] | C4 | [illegible] |
| R12 | [illegible] | E5 | 35. [illegible] | R39 | [illegible] | C4 | 30. [illegible] |
| R13 | 1·5Ω ± 10% [illegible] | E4 | 37. [illegible] | R40 | [illegible] | B1 | [illegible] |
| R14 | [illegible] | E5 | 36. [illegible] | R41 | 120KΩ ± 5% [illegible] | C1 | [illegible] |
| R15 | [illegible] | E5 | 39. [illegible] | R42 | [illegible] | C2 | [illegible] |
| R16 | [illegible] | E5 | 40. [illegible] | R43 | [illegible] | B2 | [illegible] |
| R17 | [illegible] | E5 | 41. [illegible] | R44 | [illegible] | B2 | [illegible] |
| R18 | [illegible] 4½W | E4 | 42. [illegible] | R45 | [illegible] | B3 | [illegible] |
| R19 | [illegible] | E1 | 45. [illegible] | R46 | 6·8KΩ ± 10% ¼W | B1 | [illegible] |
| R20 | [illegible] | E1 | 17. [illegible] | R47 | 2 – [illegible] ± 5% ½W IN PARALLEL. | B4 | [illegible] |
| R21 | [illegible] | F1 | 44. [illegible] | R48 | [illegible] | B2 | [illegible] |
| R22 | [illegible] | F1 | [illegible] | R49 | [illegible] | B2 | [illegible] |
| R23 | [illegible] 1½W | F5 | [illegible] | R50 | [illegible] | B4 | 18. TF1066B |
| R24 | [illegible] | F2 | [illegible] | R51 | [illegible] | B1 | [illegible] |
| R25 | [illegible] | F4 | [illegible] | R52 | [illegible] | B1 | [illegible] |
| R26 | S.I.C. | F1 | [illegible] | R53 | [illegible] | B2 | [illegible] |

| | | | |
|---|---|---|---|
| DRAWN G.F. | CHKD C.W. | USED ON [illegible] | COMPONENT LIST XD32922 |
| DATE 4.6.60 | APPD. | SHT. 1 OF 2 SHTS. | |
| TRACED MS | MARCONI INSTRUMENTS LTD. | | |

ISSUE NO. 4

| CIR. REF. | DESCRIPTION | GRID | STOCK LIST REF. | CIR. REF. | DESCRIPTION | GRID | STOCK LIST REF. |
|---|---|---|---|---|---|---|---|
| R4 | [illegible] ± 5% ½W | J4 | 51.TM6271 | | | | |
| R5 | [illegible] ± 5% ½W | J5 | 52.TM6271 | | | | |
| R6 | 1[illegible] S.I.C. ½W | K5 | 53.TM6271 | | | | |
| R7 | 100KΩ S.I.C. ½W | K5 | 54.TM6271 | | | | |
| R58 | 5·6MΩ ± 2% ¾W | M4 | 14.TF1066B | | | | |
| R59 | 4[illegible] ± 2% ½W | K5 | 20.TF1066B | | | | |
| R60 | 2[illegible]Ω ± 10% ½W | K2 | 30.TM6241 | | [illegible] | | |
| R61 | 10KΩ ± 10% ½W | L2 | 29.TM6241 | RV1 | 10KΩ ± 10% 1W | L2 | 11.TF[illegible] |
| R62 | 1MΩ ± 10% ½W | L5 | 32.TM6271 | RV2 | 22KΩ ± 10% 7½W | F2 | 12.TF[illegible] |
| R63 | 4·7KΩ ± 10% ½W | L5 | 33.TM6271 | RV3 | 50KΩ ± 10% 1W | G5 | 13.TM6241 |
| R64 | 470Ω ± 10% ½W | L5 | 56.TM6271 | RV4 | 500Ω ± 10% 1W | G4 | 14.TM6271 |
| R65 | [illegible]KΩ ± 10% ½W | L5 | 57.TM6271 | RV5 | 15KΩ ± 20% ½W | H1 | 1.TM[illegible] |
| R66 | [illegible]KΩ S.I.C. ½W | L4 | 58.TM[illegible] | RV6 | [illegible] | H1 | 1.TM[illegible] |
| R67 | 4·7KΩ ± 10% ½W | L4 | 59.TM6271 | RV7 | [illegible] | H1 | 1.TM[illegible] |
| R68 | 1MΩ ± 10% ½W | L5 | 60.TM6271 | RV8 | [illegible] | H1 | 1.TM[illegible] |
| R69 | [illegible]K ± 10% ½W | L5 | 61.TM[illegible] | RV9 | [illegible] | H2 | 2.TM[illegible] |
| R70 | [illegible]Ω ± 5% ½W | M1 | 1[illegible].TM4361/1 | RV10 | [illegible] | H2 | 2.TM[illegible] |
| R71 | 47Ω ± 5% ½W | M1 | 19.TM4619/1 | RV11 | [illegible] | H2 | 2.TM[illegible] |
| R72 | [illegible]Ω ± 10% ½W | M1 | 23.TM[illegible]41 | RV12 | [illegible] | H2 | 2.TM[illegible] |
| R73 | 2·2K [illegible].I.C. ½W | M4 | 15.TM[illegible] | RV13 | [illegible] | H3 | 3.TM[illegible] |
| R74 | 2·7 [illegible] S.I.C. ½W | M4 | 9.TM[illegible] | RV14 | [illegible] | H3 | 3.TM[illegible] |
| R75 | 3·3 [illegible] S.I.C. ½W | M4 | 11.TM[illegible] | RV15 | [illegible] | H3 | 13.TF1066B |
| R76 | [illegible] S.I.C. | M4 | 10.TM[illegible] | RV16 | [illegible] | H3 | [illegible] |
| R77 | 2·7k S.I.C. ½W | M4 | 9.TM[illegible] | RV17 | [illegible] | H3 | 15.TM[illegible] |
| R78 | 1[illegible]KΩ ± 10% ½W | M5 | 12.TM[illegible] | RV18 | [illegible] | H3 | 17.TM[illegible] |
| | | | | | | | |
| | | | | | | | |

| | | | |
|---|---|---|---|
| DRAWN G.F. | CHKD [illegible] | USED ON [illegible] | COMPONENT LIST |
| DATE 4.8.66. | APPD. [illegible] | SHT. [illegible] OF [illegible] SHTS. | X032922 |
| TRACED M[illegible] | MARCONI INSTRUMENTS LTD. | | |

INST. LTD.

ISSUE NO. 3

| CIR REF | DESCRIPTION | GRID | STOCK LIST REF. | CIR REF. | DESCRIPTION | GRID | STOCK LIST REF. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

ISSUE NO. 3

| CIR. REF. | DESCRIPTION | GRID | STOCK LIST REF. | CIR. REF. | DESCRIPTION | GRID | STOCK LIST REF. |
|---|---|---|---|---|---|---|---|
| C42 | 1PF ± 5PF 750V | L2 | 25.TM6242 | L6 | CHOKE 3½µH | J2 | 1.TM4883D |
| C43 | ·005µF ± 20% 400V | L5 | 94.TM6231 | L9 | CHOKE 6µH | K1 | 1.TM4883E |
| C44 | ·005µF ± 20% 400V | L5 | 95.TM6271 | L10 | CHOKE 6µH | K1 | 1.TM4883E |
| C45 | 27 PF SPEC. | L2 | 24.TM6241 | L11 | CHOKE H.F. | K1 | 107.TM6241/2 |
| C46 | 27 PF SPEC. | L2 | 24.TM6241 | L12 | RIPPLER CHOKE | K2 | 108.TM6241/3 |
| C47 | ·25µF ± 25% 350V | L4 | 96.TM6271 | L13 | OSC. COIL RANGE C | L2 | 1.TM6242 |
| C48 | 47PF ± 10% 500V | M1 | 20. TM4819/1 | L14 | OSC. COIL RANGE D | L2 | 4.TM6242 |
| C49 | 200PF SPEC. | M2 | PART OF TM6312 | L15 | OSC. COIL RANGE B | L1 | 2.TM6242 |
| C50 | 500PF 350V | M3 | 5.TM4883F | L16 | OSC. COIL RANGE E | L2 | 5.TM6242 |
| C51 | 500PF 350V | M3 | 6.TM4883 | L17 | OSC. COIL RANGE A | L2 | 1.TM6242 |
| C52 | 500PF 350V | M3 | 8.TM4883F | L18 | ATTEN. COIL | M2 | 21.TM4819/1 |
| | | | | L19 | MONITOR COIL | L2 | 32.TM6241/5 |
| | | | | L20 | CHOKE 95µH | M3 | 1.TM4883F |
| | | | | L21 | CHOKE 95µH | M3 | 1.TM4883F |
| | | | | L22 | ANTI-PARASITIC BEAD | J2 | 1.5 TM 6241 |
| | | | | | | | |
| | | | | | | | |
| | | | | | VALVES. | | |
| | | | | V1 | 6C4 | D2 | 1.TM6271 |
| | INDUCTORS | | | V2 | 5Z4G | L3 | 111.TM6271 |
| 1 | CHOKE 250mH | E2 | 4.TM6271 | V3 | 6CD6G | F4 | 112.TM6271 |
| 2 | CHOKE 95µH | F1 | 3.TM6271 | V4 | 6L6 | F2 | 113.TM6271 |
| 3 | CHOKE 95µH | J1 | 1.TM4883D | V5 | 6AK5 | F3 | 114.TM6271 |
| 4 | CHOKE 95µH | J1 | 1.TM4883D | V6 | 5651 | F4 | 115.TM6271 |
| 5 | CHOKE 95µH | J1 | 1.TM4883 | V7 | OB2 | F5 | 116.TM 6271 |
| 6 | CHOKE 95µH | J1 | 1.TM4883 | V8 | 6AK5 | J2 | 117.TM6241 |
| 7 | CHOKE 95µH | J2 | 1.TM4883D | V9 | TX01-10 | K2 | 118.TM6241 |

| | | | |
|---|---|---|---|
| DRAWN G.F. | CHKD F.W. | USED ON TF 2066B | COMPONENT LIST XD 32922 |
| DATE 4.8.60. | APPD. | SHT. 4 OF 5 SHTS. | |
| TRACED MS | MARCONI INSTRUMENTS LTD. | | |

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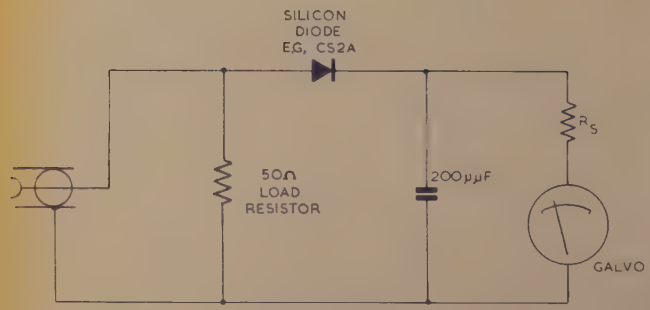
ISSUE NO. 4

| CIR REF | DESCRIPTION | GRID | STOCK LIST REF |
|---|---|---|---|
| | [illegible] | | |
| | | | |
| | | | |
| | [illegible] | | |
| VT1 | CRT114 | F4 | 103. [illegible] |
| VT2 | CRT114 | D4 | 105. TM6271 |
| VT3 | CRT1109 | [illegible] | [illegible] |
| | | | |
| | [illegible] | | |
| S1 | O.P.S.T. Toggle | [illegible] | [illegible] |
| S? | O.P.S.T. Toggle | [illegible] | [illegible] |
| S? | 3 Sec. 3 Posn | [illegible] | [illegible] |
| S? | 4 Sec. 4 Posn. | [illegible] | [illegible] |
| S? | 3 Sec. 8 Posn. | H6 | 116. TF1066B |
| S? | 1 Sec. 4 Posn. | [illegible] | [illegible] |
| | | | |
| | | | |
| | [illegible] | | |
| T1 | Mod. Trans. | [illegible] | [illegible] |
| T? | Mains Trans. | [illegible] | [illegible] |
| T? | Reactor | J1 | [illegible] |
| | | | |
| | METERS | | |
| M1 | | [illegible] | [illegible] |
| M2 | | [illegible] | [illegible] |
| | [illegible] | | |
| [illegible] | [illegible] | E6 | 73. TF1066B |

| CIR. REF. | DESCRIPTION | GRID | STOCK LIST REF |
|---|---|---|---|
| | FUSES | | |
| FS1 | 2A | D5 | 75. [illegible] |
| FS? | 2A | D5 | 75. [illegible] |
| | | | |
| FS3 | 250mA | [illegible] | 74. [illegible] |
| FS4 | 1A | [illegible] | [illegible] |
| FS5 | 1A | [illegible] | [illegible] |
| | PLUGS | | |
| PLA | 3 Pin. 5A | D6 | 1. [illegible] |
| | | | |
| | SOCKETS | | |
| | | | |
| | [illegible] | | |
| SKT? | [illegible] | [illegible] | [illegible] |
| | | | |
| | | | |
| | | | |
| | RECTIFIERS | | |
| MR1 | XU 604 | [illegible] | [illegible] |
| MR2 | XU 604 | [illegible] | [illegible] |
| MR3 | STC. C3D | E5 | 120. [illegible] |
| MR4 | C6/E | [illegible] | [illegible] |
| MR5 | C6/E | [illegible] | [illegible] |
| MR6 | C5/A | [illegible] | 100. [illegible] |
| MR7 | STC. C3D | E5 | 130 TM [illegible] |
| | | | |
| | | | |
| | [illegible] | | |
| TH1 | [illegible] | F4 | 124. [illegible] |
| | | | |
| | | | |

| | | | |
|---|---|---|---|
| DRAWN G.F. | CHKD [illegible] | USED ON [illegible] | COMPONENT LIST XD 32922 |
| DATE 4.8.60. | APPD. | SHT. 5 OF [illegible] SHTS. | |
| TRACED MS | MARCONI INSTRUMENTS LTD. | | |




NOTE:- FOR OPTIMUM WORKING, TOTAL RESISTANCE OF GALVO AND $R_S$ SHOULD BE ABOUT 8kΩ

Fig. 1. 50 OHM DIODE VOLTMETER

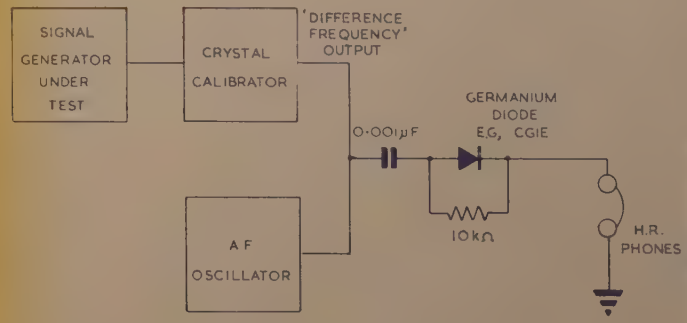
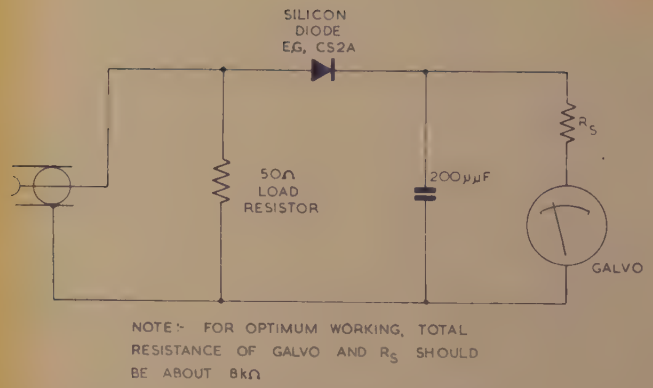



Fig. 2. INC. FREQ. TEST CIRCUIT

| TITLE | TEST CIRCUITS | | | | | | |
|---|---|---|---|---|---|---|---|
| DRAWN | DATE | CHKD | APPD | TRCD | ASSEMBLY | STOCK LIST | DRAWING NUMBER |
| M | 2-60 | | | E M T | | TF1066B | XC35452 |
| MARCONI INSTRUMENTS LTD. | | | | | | | SHEET 1 OF 1 SHEETS |

TEST CIRCUITS




NOTE:- FOR OPTIMUM WORKING, TOTAL RESISTANCE OF GALVO AND $R_S$ SHOULD BE ABOUT 8kΩ

Fig. 1. 50 OHM DIODE VOLTMETER

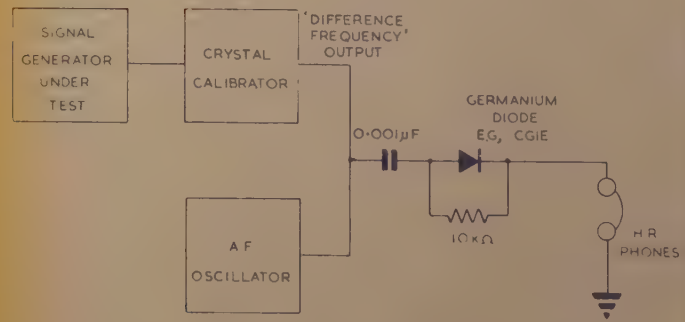



Fig. 2. INC. FREQ. TEST CIRCUIT

| TITLE | | | | | | | |
|---|---|---|---|---|---|---|---|
| TEST CIRCUITS | | | | | | | |
| DRAWN | DATE | CHKD | APPD | TRCD | ASSEMBLY | STOCK LIST | DRAWING NUMBER |
| M | 2-60 | | | E M T | | TF1066B | XC35452 |
| MARCONI INSTRUMENTS LTD. | | | | | | | SHEET 1 OF 1 SHEETS |

TEST CIRCUITS

22 AUG 1962
MARCONI
INST. LTD.

# DECIBEL CONVERSION TABLE

| *Ratio Down* | | | *Ratio Up* | |
|---|---|---|---|---|
| *VOLTAGE* | *POWER* | *DECIBELS* | *VOLTAGE* | *POWER* |
| 1·0 | 1·0 | **0** | 1·0 | 1·0 |
| ·9886 | ·9772 | ·1 | 1·012 | 1·023 |
| ·9772 | ·9550 | ·2 | 1·023 | 1·047 |
| ·9661 | ·9333 | ·3 | 1·035 | 1·072 |
| ·9550 | ·9120 | ·4 | 1·047 | 1·096 |
| ·9441 | ·8913 | ·5 | 1·059 | 1·122 |
| ·9333 | ·8710 | ·6 | 1·072 | 1·148 |
| ·9226 | ·8511 | ·7 | 1·084 | 1·175 |
| ·9120 | ·8318 | ·8 | 1·096 | 1·202 |
| ·9016 | ·8128 | ·9 | 1·109 | 1·230 |
| ·8913 | ·7943 | **1·0** | 1·122 | 1·259 |
| ·8710 | ·7586 | **1·2** | 1·148 | 1·318 |
| ·8511 | ·7244 | **1·4** | 1·175 | 1·380 |
| ·8318 | ·6918 | **1·6** | 1·202 | 1·445 |
| ·8128 | ·6607 | **1·8** | 1·230 | 1·514 |
| ·7943 | ·6310 | **2·0** | 1·259 | 1·585 |
| ·7762 | ·6026 | **2·2** | 1·288 | 1·660 |
| ·7586 | ·5754 | **2·4** | 1·318 | 1·738 |
| ·7413 | ·5495 | **2·6** | 1·349 | 1·820 |
| ·7244 | ·5248 | **2·8** | 1·380 | 1·905 |
| ·7079 | ·5012 | **3·0** | 1·413 | 1·995 |
| ·6683 | ·4467 | **3·5** | 1·496 | 2·239 |
| ·6310 | ·3981 | **4·0** | 1·585 | 2·512 |
| ·5957 | ·3548 | **4·5** | 1·679 | 2·818 |
| ·5623 | ·3162 | **5·0** | 1·778 | 3·162 |
| ·5309 | ·2818 | **5·5** | 1·884 | 3·548 |
| ·5012 | ·2512 | **6** | 1·995 | 3·981 |
| ·4467 | ·1995 | **7** | 2·239 | 5·012 |
| ·3981 | ·1585 | **8** | 2·512 | 6·310 |
| ·3548 | ·1259 | **9** | 2·818 | 7·943 |
| ·3162 | ·1000 | **10** | 3·162 | 10·000 |
| ·2818 | ·07943 | **11** | 3·548 | 12·59 |
| ·2512 | ·06310 | **12** | 3·981 | 15·85 |
| ·2239 | ·05012 | **13** | 4·467 | 19·95 |
| ·1995 | ·03981 | **14** | 5·012 | 25·12 |
| ·1778 | ·03162 | **15** | 5·623 | 31·62 |